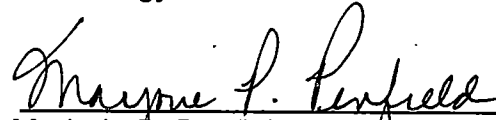
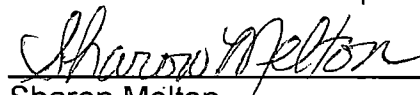


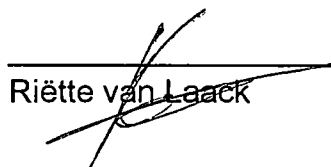
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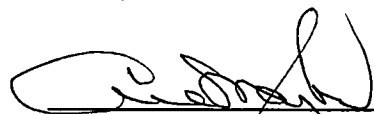

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Sensory Characteristics of Country Ham from Hogs of Different Genetic Groups

A Thesis
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Master of Science
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Susan Gail Key
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Abstract

Country ham has been a staple of southern food for centuries. Recently, other regions of the country have discovered this breakfast food. With this, there came a desire to perfect the production of the ham, a process that has long been more of an art than a science. Also, there is the desire to market a higher quality, premium product. Many factors could potentially influence the end product. The focus of this research was the relationship of the genetic group of the animals to the sensory quality of country ham. The impact of two genetic groups, Duroc and an undefined mix typical of market hogs (Market Mix), on the sensory, chemical, and physical attributes of the product was examined. The objectives of this study were to compare the hams from two genetic groups that were processed on two days in terms of their influence on sensory, chemical, and physical attributes and to determine the perception of sensory characteristics in an ideal country ham. No differences in sensory attributes between the two genetic groups were found ($p=0.2688$). However, the first processing day did yield values that were significantly higher for saltiness ($p=0.0304$) and dry texture ($p=0.0475$). Neither genetic group had deviation values for any sensory attribute different from consumer perception of the ideal country ham ($p>0.05$). Significant interactions between genetic group and processing day caused differences in hardness (texture) ($p=0.0069$). Consumers liked the Market Mix samples better than Duroc samples ($p=0.0260$). The scores for overall likeability ($p<0.0001$), aroma ($p=0.0023$), appearance ($p<0.0001$), flavor ($p<0.0001$), and texture ($p<0.0001$) were higher for processing day 1 than for day 2. There were also several trends in the results of just right scale evaluations of the products. Most of the attributes were just right. For salt intensity and flavor intensity, the responses other than just right were mainly too much. Some panelists felt that the samples were too dry and too tough. There were no differences for thiobarbituric acid

(TBA) oxidation values for the genetic groups ($p=0.1802$). The second processing day had TBA values for oxidation that were higher than those for the first processing day ($p<0.001$). No differences in cooking loss ($p=0.9695$) and shear values between the two genetic groups were found ($p=0.7097$). The mean shear value for processing day 1 was significantly higher than for processing day 2 ($p<0.0001$). Forty-one compounds were tentatively identified and 20 positively identified in the volatiles of the hams. Quantity of the volatiles between both genetic groups and processing days differed. In this study, the genetic group Duroc was not better than the mixed genetic group for production of country hams. Processing day differences were noted and may reflect difficulty in standardization of processing conditions. Further research is needed on the impact of the genetic groups on country ham quality.

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Chapter 1

Introduction

Country ham is primarily a regional product of the southern United States. The product has unique components making up its characteristic flavor. Very little research has been conducted on the sensory characteristics of this product, because of its limited regional appeal. However, the country ham industry is growing in the United States. Consumers outside of the traditional southern market are beginning to purchase the product. It is estimated by the National Country Ham Association (NCHA) that approximately 5 million country hams were produced in 2000 in the United States (Cansler 2001). The number of hams produced is expected to increase from the expansion of many of the larger producers. The value of these hams varies depending on the way they are sold, whole or sliced. The price range for an 18-20 lb ham is \$45-65, and ham slices sell for \$3-9 per lb. These hams are primarily produced in a 7-state region based upon membership information from the NCHA. Most hams are produced in North Carolina (42%) and Tennessee (26%). Missouri (14%), Kentucky (12%), Virginia (4%), Georgia (1%), and Pennsylvania (1%) are also states that have country ham production (Cansler 2001). With the growing market, there is the need for more research into what factors influence the flavor and overall quality of this product. This will allow for better production of a consistent, high quality product with the characteristic flavor that is desired by consumers.

Pure breeds may provide a higher quality end product (Stalder 2000). Normally, production of pure breeds and products from them is more expensive than products from more common mixed breeds (Touraille and others 1989). This additional cost must be off set by attributes that differ enough that consumers actually perceive them.

Curing hams is not a southern US food concept. In fact, instructions on curing hams from the third century BC from Cato have been reported (Price and Schweigert 1987). The term curing came to be associated with adding salt, sugar, saltpeter (nitrate), and nitrite to meats as a means of preservation. The possible ingredient list is now even broader with spices, ascorbates, phosphates, sodium bicarbonate, and hydrolyzed vegetable proteins being included as potential additives. As the meaning of curing has broadened, the necessity of the preservation role of curing has declined with innovations such as refrigeration. Thus, quality and sensory factors such as flavor, texture, and yield have become the reasons for curing meat (Price and Schweigert 1987). Dry curing is still used in many areas such as Virginia because of the unique cured and aged flavor that develops in dry curing process (Marriott and others 1987). The process has been altered over the years in order to produce a more flavorful and attractive product (Toldra and Flores 1998). Current researchers have focused on increased variety in the flavor and appearance of dry-cured hams (Krause and others 1978). Along with this, researchers have attempted to make the product more economical and to reduce quality problems that often occur in production.

USDA has a standard of identity for country ham. It states that it is a raw, cured, dried, smoked or unsmoked meat product produced from an intact piece of ham (USDA 2000). Country ham is made by adding dry salt or salt with optional ingredients to the ham. The cure ingredients must completely cover the exterior of the ham. Ingredients can be reapplied for complete diffusion into the ham. Country ham cannot be injected with curing ingredients or soaked in cure solutions. Optional ingredients include nutritive sweeteners, spices, seasonings, flavorings, and sodium or potassium nitrite or sodium or potassium nitrate. The final salt content must be at least 4% when nitrite or nitrate is used. The water activity in the finished product cannot exceed 0.92. The curing and salt

equalization must take a minimum of 45 d with the entire process, including drying, taking at least 70 d. The internal temperature of the ham during drying cannot be above 35 °C unless it is being held under natural atmospheric conditions. The ham must lose at least 18% of its original weight during processing. Country hams must be treated to prevent the viability of trichinae (USDA 2000).

Some sensory evaluation research has been done on this product. Some terms that are used to describe it are salty, red, rancid, dry, and tender (Countron-Gambootti and others, Moore and others 1992). Overall, there has been little research on the sensory attributes of the product. The best terms to use in sensory evaluation of the product have not been defined. The characteristics of the product that consumers find desirable and undesirable are also not known.

This study was done in order to evaluate genetic influences on country-style ham. The objectives of the study were to determine characteristics that consumers find acceptable and unacceptable in country ham and to use this information in the sensory evaluation of hams of different genetic groups, Duroc, and an unknown Market Mix. The objective was to also determine the impact of genetic group on cooking loss, shear values, oxidation levels, and volatiles content of the hams.

Chapter 2

Review of Literature

Processing

In general there are 3 main steps in the processing of country hams: curing, salt equalization, and aging. Salt penetration usually takes 28-42 d. After this, the excess cure mixture is removed from the hams and equalization of the cure ingredients lasts for approximately 14 d. Then aging follows (Marriott and others 1987). Processing is normally done under cold temperatures on a partially skinned, whole ham. The entire process normal takes a minimum of 70 d (Moore and others 1992). About two-thirds of the time period is required for the cure ingredients to soak into the ham and reach proper distribution. During aging, the typical flavor of the country ham develops. Normally, full-flavor development requires longer than just the minimum 70 d. Additional aging time can cause shrinking of the ham and increases the expense of the ham (Leak and others 1984). Methods to retard the shrinking, such as freezing or holding at cool temperatures at high humidity, disrupt flavor development. However, hams can be aged under vacuum packaging without shrinkage and flavor problems (Kemp and others 1981).

Each ingredient serves a specific role in the curing process. Salt is primarily a preservative (Romans and others 1994). It must be pure to prevent increased development of oxidative rancidity. The level of salt in cured hams is relatively high. Roman and other (1994) indicate that research is being conducted on ways to reduce its use, especially with more consumers being concerned about salt intake for health reasons. Sugar aids in flavor development. It also balances the harshness of the salt and works to retain moisture. Different forms of sugar such as brown sugar, maple sugar, and honey may be used in order to develop specialized flavors. Normally the

concentration of the sugar ranges from 0 to 2% in the end product. Nitrate primarily functions as a preservative, especially in preventing *Clostridium Botulium* growth. It also plays an important roles in color and flavor development and prevention of oxidation that will be discussed later (Romans and others 1994).

Genetic Influences

Genetic Factors

Researchers have attempted to determine the impact of breed of hogs on the quality of the meat and its end products. Fjelkner-Modig and Persson (1986) found that the breed of the animal impacts the palatability of pork.

Genetic factors can also impact the quality of the hams produced. The RN or Napole gene impacts the quality of pork products. The gene has been found mostly in Hampshire and Hampshire crosses. The meat from pigs carrying the negative allele (RN- rn+ or RN-RN-) of the RN gene is more acidic, and thus, has lower water-holding capacity (Miller and others 2000). The overall result is greater loss for the processor from increased purge losses and lower yields (Miller and others 2000). The gene reduces the yield from cured and cooked hams, but researchers also determined that the RN carrier pigs yielded a juicer ham than non-RN carrier pigs (Lundström and others 1998). In Hampshire crosses, the gene increased the intensity of the taste and aroma of the meat and decreased the shear force yield (Lundström and others 1996). However, the RN gene also increased losses in both the raw and processed meat, lowered pH, increased surface and internal reflectance values, decreased the extractibility of protein, decreased the water holding capacity, and decreased the Napole yield (Lundström and others 1998). There has been some evidence that the gene can positively impact

growth, carcass traits, and eating quality. Researchers at the University of Illinois feel that there is not enough evidence to make a conclusive decision about the impact of the gene or how wide spread it is and are doing further research (Miller and others 2000).

Researchers have also shown that the presence of the halothane genotype negatively effects meat quality even in dry-cured hams. Hams from pigs carrying the gene exhibited exudative hams, higher losses during curing, and a higher rate of poor quality end product (Costa and others 1999). Carriers of the gene have more carcass lean than non-carriers, but are more easily stressed and have overall poorer muscle quality. Researchers showed that the non-carriers had higher color and firmness scores than carriers, but no differences were found in marbling or carcass composition traits (Eggert and others 2001). When a breed such as Duroc is free of the gene it has better meat quality than breeds that exhibit the gene (Oliver and others 1993).

Duroc Pigs

Duroc pigs originated between 1822 and 1877 from the cross of Old Duroc of New York and Red Jersey pig of New Jersey (Anon 2001a). The exact lineage is really not known in that the background of the pigs used in the cross is unclear. Some think that the reds originated from Guinea Coast of Africa (Anon 2001a). Others theorize that they came from pigs brought to America by Columbus and DeSoto that are thought come from Spain and Nova Scotia (Anon 2001a). Some also feel that there is Berkshire in the Durocs (Anon 2001a). The breed was originally named Jersey-Duroc with the Duroc being in honor of a stallion belonging to the breeder of the pigs. Today the breed is described as being variable in color with a "medium length and slight dish of the face. The ears should be drooping and not held erect" (Anon 2001b). The breed is bred for

length, trimness, fine muscling, and rapid weight gain. Its red color is the dominant and preferential color with other variations existing (Anon 2001b).

Duroc pigs have been shown to exhibit qualities that are beneficial to producing dry-cured hams. Durocs can be free of the halothane gene which gives them better meat quality as previously discussed. They have also been shown to have higher intramuscular fat, which is needed to produce higher quality dry-cured hams (Oliver and others 1993). The intramuscular fat aids in the retention of flavor. It is a solvent for volatiles that are formed in the lean muscle tissue. It is also a place for further reactions of these volatiles (Flores and others 1997a).

In research comparing meat from Duroc and Large White pigs, the meat from the Duroc pigs had higher pork flavor intensity and overall liking scores. There was no difference in the tenderness. The Durocs had more marbling, but lower levels of polyunsaturated fatty acids with the exception of alpha-linolenic. This was attributed to the phospholipid content dilution with the higher overall lipid content (Wood and others 1996). When compared to Yorkshire pigs, Duroc pigs had higher overall fat content, greater marbling, lower shear force scores, and lower water content. The meat also was less acidic, more tender, and more acceptable overall (Enfält and others 1997).

In a study on the effect of the sire breed, Duroc-sired pigs produced dry-cured hams that had higher sensory scores than those from Dutch Large White, English Large White, Belgian Landrace X Landrace, and Belgian Landrace pigs (Armero and others 1999). In research on sire breed with Duroc, Hampshire, Landrace, and Yorkshire boars, the Duroc meat had the highest pork flavor intensity scores. However, there was no difference in overall acceptability among the breeds (Martel and others 1988).

When crosses with Duroc, Landrace, Large White, and Belgian Landrace backgrounds were compared, the crosses with Duroc genes had higher meat quality

than those with Belgian Landrace genes. Once again, the marbling was highest in the Durocs. The texture of the Durocs and the Large Whites was softer and more pasty, but the hams of these two breeds had the highest consumer acceptability scores (Oliver and others 1994). Other researchers found no differences in the eating quality of meat from Durocs and Large Whites in both trained and consumer panels (Edwards and others 1992). In a comparison between the meat of Durocs and British Landrace pigs, the Duroc meat was tougher and had lower flavor and overall acceptability scores. However, the Duroc meat was juicier because of its higher intramuscular fat level (Cameron and others 1990).

In research on the effect of breed on fatty acid composition, Durocs had the lowest levels of unsaturated fatty acids compared to Hampshire, Yorkshire, and crossbreed pigs. The Hampshires had the highest level of unsaturated fatty acids which makes it a greater risk for off flavors from oxidation (Villegas and others 1973).

Sensory Characteristics of Country Ham

Several characteristics influence the sensory perception of dry-cured hams. Terms from literature used to describe the product show the many parameters that are involved in the evaluation of the overall product, flavor, aroma, appearance, and texture (Table 1). The terms represent many positive and negative sensory characteristics of the product that are caused by complex interactions and reactions within the product.

Table 1- Descriptors used in consumer profiling of country ham consumers

Descriptors			
Appearance	Aroma	Flavor	Texture
Red ^{aeg}	Fresh Meat ^g	Salty ^{aceirghjkluvwxlmnopqrs}	Tender ^{bcdjuvxnmr}
Marbled ^{aeg}	Fresh Fat ^g	Acid ^{bfglqv}	Juicy ^{bdefvwl}
Bright ^{aeg}	Nutty ^{vo}	Bitter ^{beghklpqsu}	Chewy ^{fvl}
Pale ^t	Mushroom ^a	Pungent ^p	Dry ^{aegt}
Yellow -fat ^e	Meaty ^p	Dry Cured Flavor ^{ghw}	Firm ^{eitx}
Pink-fat ^e	Pork ^p	Rancid ^{begv}	Fibrous ^{ae}
Oily-fat ^e	Rancid ^a	Fresh Meat ^{gq}	Hard ^{2e}
Dry-fat ^e	Strong ^e	Butter ^{gq}	
Brown-fat ^e	Weak ^e	Hazel nut ^g	
	Cured ^e	Mushroom ^g	
	Smoky ^p	Sweet ^{be}	
	Spicy ^p	Off-Flavors ^{fwm}	
	Barnyard ^p	Fruity ^v	
	Hay-like ^p	Stale ^o	
	Pungent ^p	Tart ^{kps}	
	Acorn ^e	Intense ^b	
	Musty ^p	After-taste ^e	
		Musty ^{bg}	
		Barnyard ^{ks}	
		Hay-like ^p	
		Brown Spice ^p	
		Smoky ^p	
		Pork ^{ks}	
		Cheesy ^o	

^a Coutron-Gambotti and others 1999.

^b Moore and others 1992.

^c Kemp and others 1981.

^d Marriott and other 1987.

^e Ruiz and others 1998b.

^f Eakes and Blumer 1975a.

^g Monin and others 1997.

^h Virgili and others 1995.

ⁱ Smalling and others 1970.

^j Jacobs and others 1965.

^k Flores and others 1997a.

^l Keeton 1984.

^m Harmon and others 1992.

ⁿ Montgomery and others 1976.

^o Henrichsen and Pedersen 1995.

^p Flores and others 1997b.

^q Careri and others 1993.

^r Olson and Rust 1973.

^s Flores and others 1997c.

^t Greer and Murray 1991.

^u Kemp and others 1978.

^v Bartholomew and Blumer 1977.

^w Eakes and Blumer 1975b.

^x Langlois and others 1982.

Flavor

The unique flavor of country hams comes from a combination of several factors. Flavor components come from proteins, lipids, and carbohydrates. The final flavor is greatly impacted by non-volatile compounds, peptides and amino acids (Flores and others 1997b). The flavor is attributed to volatile components as well. Many of these volatiles come from enzymatic and non-enzymatic reactions that occur during aging of the hams (Ruiz and others 1999). The flavor compounds of country hams are water insoluble compounds (Lillard and Ayers 1969).

Researchers examining the flavor of dry-cured hams have attempted to determine which taste components of flavor are the most important. Careri and others (1993) found that dry-cured hams with high levels of tyrosine and lysine had the highest acceptability scores. Toldra and others (1992) determined that the levels of most amino acids especially lysine, glutamic acid, arginine, alanine, valine, and leucine increase during the processing of dry-cured ham due to the action of aminopeptidases. Cordoba and others (1994) also found that glutamic acid, alanine, leucine, and glycine increase in the product. Researchers found that aged, salty, and acid tastes were the most important terms used in describing Italian dry-cured ham (Careri and others 1993).

Aroma substances along with taste compounds contribute to the flavor of dry-cured hams. The acceptance of the hams by the consumer is determined by the flavor quality to a great extent (Ruiz and others 1998a). A large variety of volatiles contribute to the flavor of dry-cured ham (Ruiz and others 1999). The aroma and flavor of country ham is unique (Ockerman and others 1964). No single compound is responsible for the cured aroma (Piotrowski and others 1970). Instead, researchers think that the cured aroma is made up of a balance of a variety of aroma compounds (Flores and others 1997a).

Because aroma compounds are important to the overall flavor of dry-cured hams, researchers have evaluated different methods of determining the volatiles. Solid phase micro-extraction (SPME) is a method of analyzing the volatiles content of solid food products (Nielsen 1998). The method exposes a polymer-coated fiber in the headspace of a sample vial. The analytes are absorbed onto the coating. The fiber is allowed to come to equilibration, and then, the fiber is moved to the injection port of a gas chromatograph where the volatiles are desorbed onto the column for analysis (Nielsen 1998). This is a useful method for research in dry-cured meat products because of its short time, absence of solvents, relatively low cost, and ease of use. Ruiz and others (1998a) found that SPME reveals a large range of compounds from dry-cured hams and is a means of isolating compounds found during sensory evaluation of the products. It is limited in that the time and temperature of extraction can impact the chromatographic area of less volatile components. Extended exposure of the samples to high temperatures can also result in the generation of thermal compounds (Ruiz and others 1998a).

Ockerman and others (1964) found that carbonyl compounds played a major role in the flavor of country hams. They also found that these compounds increased with aging. This agrees with other researchers who found flavor compounds developed during the aging process (Lillaird and Ayres 1969). They also determined that heating increased the rate of reactions that lead to the characteristic flavor of country ham. Some of the precursors for these reactions may be lipid degradation products. Carbonyl products that come from oxidation of the lipids add to the flavor. Amino acids have also been shown to be involved in the flavor of country ham. During the aging of country hams, the amino acids undergo changes (McCain and others 1968). These changes are thought to correlate with changes in flavor of the hams during ripening. Therefore, amino

acids most likely are important precursors of flavor volatiles in country ham, especially when the ham is heated (McCain and others 1968). Careri and others (1993) determined that methyl short-chained esters and alcohols were the most important volatiles in determining overall consumer acceptability of Italian dry-cured ham.

Buscailon and others (1993,1994) found that the volatiles content of cured hams could be attributed to the lipid oxidation products, amino acid degradation products or a combination of both. The researchers showed that French dry-cured hams have similar increases in volatile compounds over time especially during the beginning months of aging. Propanone was at the highest level. Other compounds found were ketones, alcohols, and aromatic hydrocarbons. In an additional study, researchers found high levels of esters in Parma ham (Bolzoni and others 1996). They also detected ethyl esters, carbonyls, and alcohols. Flores and others (1997a) found alcohols, aldehydes, ketones, aliphatic hydrocarbons, esters, aromatic hydrocarbons, chloride compounds, nitrogen compounds, furans, a carboxyl acid, a sulfide compound, and branched chain hydrocarbons in Spanish Serrano dry-cured hams. The ketones, esters, aromatic hydrocarbons, and pyrazines correlated with the pleasant aroma of the hams. The researchers concluded that with the exception of the sulfide compounds, methyl branched aldehydes, and pyrazines, the volatiles resulted from lipid oxidation. The exceptions were products of Strecker degradation of amino acids (Flores and others 1997a).

Work has been done to determine the exact differences between cured and uncured pork volatiles content. Cross and Ziegler (1965) found that uncured ham had high levels of hexanal and valeraldehyde while virtually none was present in cured ham. The uncured hams had higher levels of butyraldehyde, propionaldehyde, and acetaldehyde than in the cured hams. The researchers also found that the levels of

branch chained aldehydes did not differ significantly between the cured and uncured product. Both were also found to contain acetone, hydrogen sulfide, and methanethiol. The researchers concluded that the cured flavor came from precursors other than triglycerides and that the aromas from cooked meat came from carbonyl compounds formed by the oxidation of fat. The overall differences in volatiles of the cured and uncured hams were attributed to the reduction of lipid oxidation by nitrite in the cured hams (Cross and Ziegler 1965). Mottram and others (1984) found that uncured pork had many unsaturated and aromatic benzaldehydes that were not in cured pork. The volatiles of the cured pork included benzonitrile, phenylacetonitrile, and 4 alkyl nitrates that were not in the uncured pork volatiles. The researchers concluded that the nitrite was not preventing oxidation, but it was modifying it (Mottram and others 1984). In further research, Mottram (1984) again found the same compounds in cured pork volatiles. Mottram determined that the nitrogen compounds were formed by reaction of fatty acids with sodium nitrite. In thermal oxidation of the unsaturated fatty acids, free radical mechanisms normally occur. The alkyl nitrates may be the result of nitrous acid or free nitrogen radicals becoming involved in these mechanisms. Nitrite may also be reacting with other flavor precursors to produce other cured meat flavor compounds (Mottram 1984).

Many characteristics can influence flavor reactions involving proteins and lipids. The characteristics of the raw ham, including age, crossbreeding, and pH, influence the action of the enzymes. Processing conditions also play a role. Temperature, time, water activity, redox potential, and salt concentration can impact the action of the enzymes. Thus, it is very important to maintain optimum conditions in order for desirable flavor development and maintenance of uniform end product (Toldra and others 1993).

Factors important to panelist perception of cured flavor have also been examined. Score cards, sample appearance, and oxidized or rancid flavor impact panelists impression of cured flavor (Price and Greene 1978). The type of product, internal processing temperature, and level of fat in the sample did not influence panelists. Also, the researchers determined that cured flavor could be formed using only NaCl without NaNO₂. However, the NaNO₂ did intensify the cured flavor and made a more desirable product.

Fat Content

Often the pigs used in cured pork products display a high degree of intermuscular fat. Researchers found that this trait gives sensory quality characteristics to the products (desired flavor and intensity) and slows moisture loss, maintaining a more tender, juicy product (Garcia and others 1991; Anteguera and others 1994).

Back fat seems to be related to the amount of oxidation. When back fat is 5.08 cm or greater oxidation levels are lower than when the level of back fat is 3.81 cm or less. The exact cause of this was not reported because it was noted that the free fatty acid content did not differ (Rogers and others 1962).

Oxidation

A high content of intermuscular fat can play a role in the extent of flavor development from reactions with this fat. Oxidation is of primary concern. Many of the volatile components in country hams are products of lipid oxidation (Berdague and others 1993). A fatty acid that contains at least one double bond can be subject to oxidation (Romans and others 1994). An oxygen molecule cleaves the double bond and

replaces it. Aldehydes and shorter fatty acids are formed. Often these products produce undesirable flavors in fat and potentially the surrounding tissue. Pork with its high content of unsaturated fatty acids (oleic, linoleic, and linolenic) is more prone to oxidation than other meats such as chicken and beef (Price and Schweigert 1987). Oxidized flavors are thought to originate from membranal phospholipids during storage in both raw and cooked meats (Morrissey and others 1994).

Oxidation is influenced by several factors. Oxygen obviously increases the rate of oxidation. Elimination of oxygen is the most common way to reduce oxidation. Temperatures should be maintained at low levels, because oxidation increases at increased temperatures. Ultraviolet light can also speed oxidation. Copper, iron, manganese, cobalt, and lead can increase the oxidation rate. Salt makes pork fat more vulnerable to oxidation (Price and Schweigert 1987). Shortening the salting in curing decreases oxidation, but makes rancid, fatty, and buttery flavors become more apparent and negatively impacts the flavor of dry-cured ham (Coutron-Gambotti and others 1999). Supplementing swine diets with α -tocopheryl increases the oxidative stability of low-nitrite cured products (Walsh and others 1998). The supplementation results in higher levels of α -tocopherol remaining in the muscle tissue. In addition to the increased oxidative stability, the hams also exhibit a resistance to color fading and reduced weight loss of ham slices that are held under fluorescent light (Isabel and others 1999). The use of butylated hydroxyanisole (BHA) and Tenox 7 (BHA, propyl gallate, and citric acid) also significantly reduces oxidation in country hams (Lail and others 1970). Oxidation is also reduced by nitrite as shown by Freybler and others (1993) who determined that nitrite interacts with unsaturated fatty acids forming nitro-nitroso adducts. This makes the fatty acids less likely to oxidize.

High oxidation levels have been shown to significantly lower flavor scores in dry-cured hams, but did not affect overall satisfaction ratings (Rust and Olson 1973). Therefore, Rust and Olson (1973) concluded that other factors such as tenderness are more important than flavor, including oxidation off-flavors in determining overall consumer satisfaction.

TBA is a commonly used method of measuring oxidation in pork products. TBA values are correlated with sensory acceptability scores in pork (Younathan and Watts 1959). The researchers found that sensory acceptability scores decreased as the TBA values of the meat increased. They also showed that curing salts and antioxidants restricted the oxidation in pork so that there was no increase in TBA values over a 7-d time period. Uncured pork showed a marked increase in TBA values and a large decrease in sensory scores over the same time frame. However, there is an increase in TBA values after storage of cured meat when color changes become apparent. The researchers found values for TBA in cured meat to be no higher than 1.5. The researchers found that the difference in oxidation level dealt with the pigments in the cured and uncured meats. The ferric hemochromogen pigment in the uncured meat is a catalyst for the oxidation of the unsaturated fat in the pork. In contrast, the ferrous nitric oxide hemochromogen in the cured meat does not act as a catalyst.

Color

The color of cured meats comes from reactions with nitrate or nitrite during processing (Price and Schweigert 1987). This was first an accidental development from impure salt. The actual preservation value of nitrate was later discovered and the ingredient became intentional. The color results from a series of reactions with the nitrate. The nitrate is reduced to nitrite, which is further reduced to nitric oxide. This

compound forms a complex with heme pigments to form the final cured meat color. This color can be used as a quality indicator in cured meats (Price and Schweigert 1987). Consumers use color as an indication of meat freshness (Lanari and others 1995). Meat color will fade and taken on a brown discoloration in the presence of air and light (Price and Schweigert 1987). This is attributable to pigment oxidation, which is related to lipid oxidation (Akamittath and others 1990). Normal cured meat color is an additional benefit of the nitrate, which serves to inhibit *Clostridium botulium* growth along with flavor and texture development (Price and Schweigert 1987).

Cured hams should have a pale pink color that is opaque (Price and Schweigert 1987). The normal color of cured meats comes from nitrosylmyoglobin (uncooked) and dinitrosyl hemochrome (cooked). Both of these originate from nitric oxide. In the dinitrosyl hemochrome there are 2 nitric oxide molecules per heme. Discoloration can be caused by a number of compounds. Metmyoglobin is responsible for brown colors when the meat is under-cured or too little nitrite is used. Green appearance is attributed to nitrimetmyoglobin from too much nitrite and acid. Hemichromes from aging and acid cause brown discoloration. The formation of choleglobin during oxidation gives the meat a green appearance. Bile pigments that are end oxidation products can also cause a brown appearance in the meat (Price and Schweigert 1987). The color can be stabilized by supplementation of the pig diet with α -tocopheryl acetate (Walsh and others 1998).

Texture

Just as color impacts the initial perception of quality, texture impacts the overall final perception of the product. It is a main sensory characteristic that consumers perceive (Tabilo and others 1999). In meat products, tenderness and juiciness influence

how the consumer rates the product (Szczesniak 1990). Tenderness is associated with quality and nutrition. Lack of tenderness, or toughness, is undesirable. Juiciness is "appetizing and appealing in itself, it wets and refreshes the mouth and its absence violates expectations and lowers the perceived quality" (Szczesniak 1990). Quality perception of dry-cured ham is greatly influenced by texture and mechanical properties, which originate from technological parameters and the raw materials used (Guerrero and others 1999). The technological parameters include aging times and temperatures, salt concentration, brine injection, skinning, and deboning. Guerrero and others (1999) list genetics, enzyme activities, and pH as factors in the raw materials.

The texture is greatly influenced by the natural enzymes in the cured hams. Structural proteins are broken down by proteolysis during dry curing, causing the gradual increase in tenderness of the ham. If extensive proteolysis occurs the texture can be affected and the consumer acceptability negatively impacted (Tabilo and others 1999). The main enzymes responsible for the tenderization in dry-cured hams are proteinases including cathepsins B, D, H, and L and calpains (Toldera and others 1993). Exopeptidases such as peptidases and aminopeptidases are also involved in the proteolysis (Toldra and Flores 1998). The actual rates and levels of reaction of the enzymes is influenced by the age and genotype of the hogs used for the ham, the conditions in processing such as temperature, time, and water activity, and the curing ingredients (Toldra and others 1997; Toldra and Flores 1998).

Rogers and others (1965) researched if the curing process could be accelerated by addition of papain. The researchers concluded that the papain produced a more tender product in terms of Warner Bratzler shear tests. However, panelists felt that the product was mushy and gave the hams low sensory acceptability scores (Rogers and others 1965). Jacobs and others (1965) found that pancreatic lipase and papain-treated

hams had lower tenderness scores than untreated hams, which were preferred overall. The lipase-treated hams were liked better than the papain treated hams partially because of the mushy places in the hams. The lipase-treated hams were not as tender as the control and the papain-treated hams (Jacobs and others 1965). Smalling and others (1970) studied the effect of papain injection in the hams antemortem. They found that the treated hams were more tender than the untreated hams. However, they were found to be too tender for consumer acceptability (Smalling and others 1970).

Tabilo and others (1999) have examined the effect of meat quality (Pale Soft Exudative (PSE), Red Soft Exudative (RSE), Red Firm Normal (RFN), and Dark Firm Dry (DFD)) and gender on the texture and enzyme breakdown of the proteins in dry-cured hams. PSE hams were less springy, hard, cohesive, and chewy than RFN hams, which corresponded to a higher level of proteolysis in the PSE hams. Female pigs produced hams that were not as hard as hams from male pigs (Tabilo and others 1999). Virgili and others (1995) determined that a mushy mouthfeel (and white film formation) could be contributed to high proteolytic activity (especially Cathepsin B) and low-protein content in hams. They suggested avoiding hams with these characteristics in dry curing.

Texture is also impacted by intramuscular fat. In general, greater levels of intramuscular fat result in a more tender product. Harrington and Pearson (1962) found that pork with lower levels of fat were on average tougher than those with higher levels of fat.

Factors Affecting Sensory Quality

Several researchers have examined the impact of various changes on sensory quality of dry-cured ham. Most focused on changes in cure ingredients and processing

methods. Since none of the research studies are directly related to the parameters of this study, they will only be briefly discussed here.

Cure Ingredients

Salt Content - One area of research is the composition of the cure mixture used. Coutron-Gambotti and others (1993) examined the impact of lowering the salt content on the sensory properties of dry-cured ham. The appearance of the hams was not impacted. However, the hams with lower salt content tasted less salty and had greater levels of rancid, fatty, and buttery aroma. Bartholomew and Blumer (1977) found that higher salt level (7%) produced country hams that had higher levels of aged flavor and nuttiness.

Olson and Rust (1973) substituted low pro-oxidant and antioxidant salts for regular curing salt. The hams cured with antioxidant salt had higher flavor scores than those with the regular and low pro-oxidant salt. There was no difference in the overall satisfaction between the hams (Olson and Rust 1973). Keeton (1984) replaced normal salt with various percentages of potassium chloride. The researcher found that hams with 66.7 and 100% KCl had lower aged flavor levels, higher cohesiveness, and higher levels of bitterness than hams with NaCl. Panelists found these hams to be unacceptable. The hams that had 33.3% KCl tasted slightly more bitter than hams cured with regular salt.

Nitrite and Nitrate - Eakes and Blumer (1975a) studied the use of nitrate, nitrite, and a combination of both at varying levels on the sensory properties of country hams. At 70 ppm, hams with just nitrite or the combination had a slightly more acceptable aged flavor. Hams treated with only nitrate and the combination had better flavor scores and greater overall acceptability. Eakes and Blumer (1975b) also compared the use of just

salt, nitrite, nitrate, and the combination of both at the same levels. There were no flavor differences among the hams. The nitrite-produced hams that had higher cooked color elasticity, cohesion, and hardness scores than the hams with just salt and sugar. The hams were also perceived to be less acidic than the untreated hams (1975b). In another study, researchers looked at the potential of using NO gas exposure instead nitrite or nitrate (Marriott and others 1983). There was no difference in the sensory quality of hams produced with the NO and 2 levels of nitrite.

Additional Ingredients - The potential preservative effects of additional ingredients on dry-cured hams have also been examined. Kemp and others (1981) studied the impact of dipping hams in potassium sorbate in order to retard mold growth. They found that it did not influence sensory perception the tenderness, flavor, saltiness, and overall satisfaction in the hams.

Processing

Slaughter Procedures - Some investigators have started at the beginning of processing to determine if slaughter procedures impact the sensory quality of hams. Montgomery and others (1976) found that normally skinned hams had higher scores for flavor than unskinned or completely skinned hams. They also determined that unskinned hams were the most tender and that overall eating satisfaction and rancidity were not impacted by skinning method. Hams that were dehaired by scalding instead of singeing were perceived to be saltier and more pungent with more intense dry ham, rancidity, and hazelnut aromas by panelists (Monin and others 1997). The scalded hams also had less of a fresh meat aroma, were drier, and were less mellow.

Storage Prior to Curing - Researchers have looked into the impact of freezing and refrigerated storage time on sensory properties of dry-cured hams. Kemp and others

(1978) found that freezing hams prior to curing did not significantly influence color, aroma, general appearance, and palatability ratings. Bañón and others (1999) also determined that freezing hams before they were cured did not impact color and acceptability scores. The length of storage at refrigerated temperatures (3 and 6 d) had no impact on the sensory perception of dry-cured hams (Langlois and others 1982).

Tumbling - Tumbling has been researched as a means of accelerating curing, and therefore, has also been studied for its impact on sensory properties of cured hams. Marriott and others (1984) found that tumbling did not influence the sensory perception of flavor, but it did cause color and color stability differences. Krause and others (1978) found that tumbled hams had higher external appearance, internal color, sliceability, taste, and aroma scores than non-tumbled hams. The researchers also found that tumbling times influenced the same characteristics and consistency. In another project, Marriott and others (1987) found that tumbling time did not influence taste factors in dry-cured hams. Hams that were tumbled longer were more tender and juicy after 40 d.

Meat Quality - Researchers have also examined the influence of the quality of the starting meat on the sensory quality of the resulting dry-cured ham. Guerrero and others (1999) compared dry-cured hams produced from normal and DFD (dark, firm, and dry) hams. The DFD end products were softer, pastier, more crumbly, and more adhesive than the normal hams.

Smoking - Smoking is considered to be an optional step in the production of dry-cured hams. Its use varies depending on the region in which the product is produced. Langlois and others (1982) examined the influence of smoking on sensory perception. They found that there was no difference in sensory palatability traits between hams that were and were not smoked.

Needle Tenderization - Some researchers have looked at the effect of needle tenderization on sensory properties of hams. Kemp and others (1986a) found that needle tenderization did not significantly influence sensory perception of the color, aroma, and general appearance of dry-cured hams with the exception of increasing the salt intensity. In an additional study, Kemp and others (1986b) determined that needle tenderization caused slightly lower flavor and overall satisfaction scores.

Processing Time - In an effort to reduce costs associated with the production of dry-cured hams, many researchers have experimented with the effect of differing processing times and evaluated their impact on the sensory quality of the hams. Researchers concluded that hams ripened for longer periods of time had greater flavor strength, cured flavor intensity, and aftertaste intensity (Ruiz and others 1998b). The longer processing time also caused differences in appearance. Researchers also found that longer processing times increased boar taint, barnyard flavor, sourness, and saltiness (Flores and others 1997c). In another study, Flores and others (1997b) determined that the intensity of boar taint, barnyard, smoky, serum, pungent, sour, salty, astringent flavors were increased by a longer processing time. Hinrichsen and Pedersen (1995) looked at changes in flavor compounds over time in dry-cured hams. The nutty, cheesy, and salt tastes all had sigmoidal increases over time. The stale and fatty flavors initially decreased, but showed a slight increase near the end of storage. There was no difference in the intensity of the meaty flavor over time.

Country ham is a very unique product with each ingredient and processing step playing an important role in flavor and texture development. The product quality can be influenced by genetic factors, such as the RN gene and halothane gene. Changes in any of these factors can influence the sensory perception of the product.

Chapter 3

Materials and Methods

In this study the impact of 2 genetic groups on sensory and quality attributes of country hams was investigated. The groups used were Duroc and a Market Mix of unknown genetic background and were processed on 2 separate days a week apart. The country hams were then examined using sensory, chemical, and physical testing methods. Two phases of sensory panels were conducted. The first phase, or user panel, consisted of panelists who ate country ham at least once per year. The second phase, or volunteer panel, was open to anyone who wanted to taste ham.

Experimental Design

The experimental design was a randomized block design. The 4 treatment combinations came from the 2 genetic groups and 2 processing days. The samples were processed 12 mo before the start of the research and evaluated by sensory evaluation panelists in 2 phases. In the first phase (user panel), panelists received 2 samples per session with 2 sessions. The panelists were given samples from both genetic groups but a single processing day in each panel session. Therefore, they received all four possible treatment combinations over the 2 d. Sample order was balanced across processing days and within testing sessions. In the second phase (volunteer panel), panelists received 2 samples in a single session. The samples were from a single processing day and both genetic groups. Therefore, the panelist only received 2 of the 4 possible treatment combinations. Equal numbers of panelists received samples from each of the 2 processing days.

Country Ham Production

The hams were prepared in advance of the research with enough time for proper curing of the product (Stalder 2000). Arrangements were made by the National Swine Registry (NSR) for purebred Duroc market hogs to be delivered to SouixPreme Packing Co (Sioux Center, IA) on two marketing days in sufficient quantity (approximately 150 or more) for the research. Hams of unknown genetic background were purchased from the same facility and another unnamed processor. The hams (7.7-9.1 Kg) were processed on 2 test days so that 30 hams of each genetic type were processed on the same day (the number of hogs sampled and number of hams sampled were determined using the variance of pH from published research) (Stalder 2000). The NSR certified that the Durocs were free of the PSS gene. Glycolytic potential, as testing for the Napole Gene was not done, because it was assumed that presence of the gene is considered to be rare (or none) in the breed. The hams were sent to Clifty Farms Country Hams (Paris, TN) for curing. All hams were cured and further processed using the company's normal operating procedures for commercial production of country hams. For this research, 12 hams from each processing day and genetic background (48 total) were randomly chosen. The hams were sliced and vacuum packaged in groups of 6 center slices. The packages were labeled with an identification number. The hams were transported to The University of Tennessee, Knoxville, where they were stored under refrigeration temperatures (1-3°C) until the beginning of the study.

Ham Characteristics

In a separate portion of the overall study, measurements were taken on the hams for pH, moisture, and salt content (Tables 2-3). In general, the mean values and range of values for the components were the same for both all the samples obtained and the ones randomly chosen for use in this portion of the study. There were no differences in the pH and moisture (raw) values for the genetic group or days ($p>0.05$). The values for moisture (cured) did not differ between the days ($p>0.05$). The mean moisture from the Duroc samples was higher than that of the Market Mix samples ($p<0.05$). There were no differences between the 2 genetic groups in terms of salt levels ($p>0.05$). The fat content of the raw samples from day 1 was higher than that of day 2 ($p<0.05$). There were no differences in the fat content between the 2 genetic groups ($p>0.05$). A significant interaction ($p<0.05$) showed that Market Mix samples did not differ in salt content by day (4.6 and 4.2%). However, salt content of Duroc was higher on day 1 (5.2%) than on day 2 (3.6%).

Consumer Survey

The literature on the sensory evaluation of dry-cured hams was used to compose a list of terms to describe the product. All available literature that contained sensory evaluation of dry-cured hams was reviewed. The terms for the appearance, aroma, taste, and texture of dry-cured hams were documented. The type of panels (trained, experienced, consumer, etc.) and the sensory tests used were recorded. The

Table 2 - Comparison of proximate analysis values for country ham samples from 2 processing days (across 2 genetic groups) used in this study for the user panel ^a

Measurement	n	Sample ^b	Day1		Day 2	
			Mean	Range	Mean	Range
pH	134	All	6.22b	5.86-6.65	6.38a	5.76-7.27
	24	Study	6.24	6.09-6.47	6.34	5.99-7.00
Moisture, raw (%)	128	All	75.3	71.5-80.3	75.4	71.4-80.0
	24	Study	74.5	71.8-76.5	75.8	71.6-79.9
Moisture, cured (%)	133	All	62.5	55.4-69.0	63.1	54.8-69.7
	24	Study	61.8	56.4-65.4	62.9	58.0-67.5
Salt (%)	134	All	4.7a	3.2-6.8	3.8b	2.5-5.6
	24	Study	4.9a	3.2-6.4	3.9b	2.8-4.9
Fat, raw (%)	128	All	4.6a	2.1-8.1	3.3b	1.5-8.9
	24	Study	4.9a	2.6-7.3	3.0b	2.0-5.1

^a Values within rows with differing letters are significantly different (p<0.05).

^b All includes the hams for each day and genetic group combination; Study includes those used for user panel.

Table 3 - Comparison of proximate analysis values for country ham samples from 2 genetic groups (across 2 processing days) used in this study for a user panel ^a

Measurement	n	Sample ^b	Duroc		Market mix	
			Mean	Range	Mean	Range
pH	134	All	6.33	5.76-7.11	6.28	5.86-7.27
	24	Study	6.33	5.99-7.00	6.28	6.10-6.42
Moisture, raw (%)	128	All	75.6	71.4-80.3	75.2	71.4-78.6
	24	Study	75.6	73.6-79.9	74.7	71.6-77.0
Moisture, cured (%)	133	All	64.7a	59.7-69.7	61.0b	54.8-65.5
	24	Study	64.4a	62.7-67.5	60.2b	56.4-65.0
Salt (%)	134	All	4.3	2.5-6.8	4.3	2.5-6.0
	24	Study	4.4	2.8-6.4	4.4	3.2-5.8
Fat, raw (%)	128	All	3.9	1.5-8.9	3.9	1.5-8.1
	24	Study	3.8	2.0-7.3	4.2	2.2-6.7

^a Values within rows with differing letters are significantly different (p<0.05).

^b All includes the hams for each day and genetic group combination; Study includes those used for user panel.

resulting list of terms was used in formatting a questionnaire to be presented orally to consumers of country ham.

This type of survey was used since no reports were found of previous research to determine what consumers of country ham desire in the product and what they dislike in the product. The people were surveyed in order to gain a base understanding of what consumers of the product find desirable and undesirable. Individuals (27) were asked to describe the appearance, aroma, flavor, and texture of country ham. Responses that matched terms already used in sensory studies were marked and additional terms were recorded. Then, panelists were asked to tell what attributes they liked and disliked in country hams. These results were also recorded. Finally, the individuals were read the list of descriptors gained from the review of literature and asked to indicate if they felt that each term described the product. A complete list of terms used is on the evaluation form (Appendix, p.102-105). Demographic and consumption information was also obtained from the panelists. The results of the consumer survey were used as a basis for the questions in the sensory evaluation portion of this study. The information was also useful in interpreting results from other portions of this study. The individuals surveyed were considered for future use as members of user panels.

Sensory Evaluation-User Panel

Panelists for the user panels were recruited based upon their consumption of the product. All panelists had to eat country ham at least once a year. Preference was

given to individuals who consumed the product most frequently. The panelists also had to be able to complete 2 panel sessions, 1 per day for 2 days.

The panels were spread over a 2-mo period. For each set, there was 1 panel per day for 2 d. For each set of panels, 12 panelists were selected. There were 6 sets of panels. In all, 72 panelists were used. Each set of 12 panelists was divided into groups of 3 because of a limited number of samples that could be prepared at a given time. The groups were assigned 25-min time slots for panel participation to ensure testing within reasonable time of heating.

Each panelist received samples from the same location on the ham slice each time. The locations were whole muscles (semimembranosus and biceps femoris) or a group of smaller muscles (quadriceps femoris). Each panelist was assigned one of these locations. The individual samples were cut from the ham slices and placed in re-sealable plastic bags. They were stored under refrigeration temperatures until they were cooked when the panelists arrived.

The panelists also received the sample from the same slice within the package. There were 6 slices of ham per package. The middle 4 slices were used for sensory evaluation.

The samples were cooked before serving. They were fried on an electric griddle at 177 °C (Hobart model HG2, Troy, OH) for 1 min and 40 sec on each side. The temperature was selected based on recommendations from the Meat Extension Specialist at The University of Tennessee (Melton 2001). The recommendation was made so that the sample was heated to a temperature acceptable by the panelists without negatively impacting the quality of the texture of the product.

The number of samples per session was limited to 2 to prevent overwhelming the panelists and impairing their judging ability because of the extreme saltiness of the product. Over the 2 sessions, each panelist received samples from the 4 treatment combinations of genetic group and processing day, as described in Experimental Design (p 24).

The samples were served on plain white plates (Corelle, Corning, NY) that were coded with 3-digit random numbers. The plates were presented on plastic trays with white paper liners. The panelists were given a stainless steel knife and a fork for eating the samples. Panelists were also given spring water (Mountain Valley, Hot Springs, AR) in a clear glass for rinsing before and after each sample.

The questions on the sensory scorecard were based upon the results of the previous consumer survey. The questions dealt with overall opinion, color, aroma, flavor, and texture. The question for overall opinion had a 15-point hedonic scale. The format was 15-point intensity scales for the color, aroma, flavor and texture questions. A sample score card is in the Appendix (p.106-109).

Prior to tasting samples, the panelists were asked to score an "ideal" sample of country ham. With this, they used their memory and opinion of country ham in order to evaluate what they would have in their ideal slice of country ham. A copy of the "ideal" scorecard is in appendix (p.106). The ideal was scored using the same questions as the actual samples with the omission of the overall opinion question. The purpose of the ideal was to give a reference point of what the consumers actually desired (Szczesniak and others 1975). This was used to compare the results from the evaluations of the actual ham samples to see if they differed in how they met consumer expectations.

Sensory Evaluation- Volunteer Panel

The second portion of the sensory evaluation was an open panel. Panelists were not required to have previously consumed country ham. The panelists had to attend a single panel session. The panelists were not told that the ham was country ham, but were informed that they would be sampling ham that day.

The panelists were given 2 ham samples, 1 from each genetic group. They were only given samples from 1 processing day. The order of presentation of the samples and the pairs was balanced. The samples were cooked and presented in the same method as was used in the user panel.

The scorecard (Appendix p 110-115) had several sections including hedonic, just right, preference, sample identification, and product familiarity questions. There was also a section for demographic information.

A 9-point hedonic scale was used on a portion of the sensory scorecard. The anchors were like extremely and dislike extremely. Panelists were asked to evaluate the samples overall. The panelists also indicated how well they liked the aroma, appearance, flavor, and texture of the product. This scale was used in order to gain information on how well the panelists liked the ham samples in terms of these attributes.

Just right scales (5-point) were also used on the sensory scorecard to evaluate component levels within the product. The anchors were much too much and much too little. The panelists rated the aroma intensity, color, flavor intensity, saltiness, sweetness, moistness/dryness, and tenderness of the samples in these scales. The

just right scales were used to reveal trends in how the panelists perceive the intensity of these characteristics in the ham.

A preference question was included on the scorecard given with the second sample. The panelists were asked to indicate which of the products they liked best, if either. They were also given the option of stating that they disliked both products equally. This question was utilized in order to determine if the consumers preferred one of the samples over the other.

In the final portion of the scorecard, the panelists were asked to identify the product being tasted from a given list of hams. This list was included in order to see if the evaluations that the panelists were giving were based upon a true understanding of what they were eating. The types of ham given to choose from were country, smoked, cured, salt cured, sugar cured, dry-cured, wet cured, baked, city, fresh, Smithfield, and Virginia. Finally, panelists indicated with which of the types of hams listed they were familiar. The questions gave insight into the types of hams that are potentially being consumed by the panelists.

Oxidation-Thiobarbituric Acid Analysis

The level of oxidation in the samples was measured using the thiobarbituric acid test (TBA) method that was developed by Tarlidgis and others (1960) and later modified by Rhee (1978). Samples from the product used in the user sensory evaluation were evaluated. The uncooked samples were refrigerated until just prior to cooking on the same days as the sensory panels. A 10-g sample of the ham was mixed with 5 mL 0.5% propyl gallate in alcohol, 5 mL 0.5% sodium ethylenediaminetetracetic acid (EDTA), and 40 mL deionized water (Sigma, St. Louis, MO). The sample was

homogenized in a homogenizer (Brinkmann Polytron, Model PT 10/35, Westbury, NY) for 2 min at setting 8. Then, 2.5 mL of 4N hydrochloric acid was added to the mixture. The mixture was placed in an 800-mL Kjeldahl flask. Deionized water was used to wash the mixture into the flask. Anti-foaming agent (Arthur H. Thomas Co., Philadelphia, PA) and boiling beads were also placed in the flask.

The standard was made by mixing 1 mL of 10^{-4} M 1,1,3,3-tetra-ethoxypropane (TEP), 2.5 mL 4 N HCl, and 92.5 mL of deionized water together (Sigma, St. Louis, MO). The standard and samples were distilled to collect 50 mL of distillate in 15 min. A sample of each distillate (5 mL) was mixed with 5 mL of TBA reagent (0.02 M 2-thiobarbituric acid) in a test tube. The standards used for comparison were prepared as shown in Table 4.

The test tubes were incubated for 40 min in a 90°C water bath. The mixtures were poured into cuvettes. Then, the absorbance was read on a double-beam spectrophotometer (Shimadzu, Model UV-2101PC, Kyoto, Japan) with the wavelength set at 532 nm. The absorbance readings and the concentration of the standards were used to fit a linear regression equation for each distillation run. The equation was used to determine the milligrams malonaldehyde/kilogram ham as the TBA number.

Cooking Loss

The percentage cooking loss was measured for the first slice from every package used in sensory evaluation testing. The full slices were weighed prior to cooking (Ohaus, Navigator model N1H110 d=0.5g, Florham Park, NJ). The slices were cooked using the same method as for sensory evaluation sample preparation

Table 4 - Concentrations of malonaldehyde and the amount of standard, water, and TBA reagent needed to make them for oxidation measurement in country ham samples

Concentration (mg malonaldehyde)	Standard (mL)	Deionized water (mL)	TBA reagent (mL)
0	0	5	5
1×10^{-6}	1	4	5
2×10^{-6}	2	3	5
3×10^{-6}	3	2	5
4×10^{-6}	4	1	5
5×10^{-6}	5	0	5

Then, the slices were weighed immediately after cooking. They were also weighed a second time after the fat was drained onto paper plates for approximately 20 min. Percentage cooking loss values were determined from this information.

Texture – Shear Values

Texture measurements were taken on the slices heated for the cooking loss determination. The slices were stored over night in a refrigerator to ensure that all samples were thoroughly and uniformly cooled. Strips (2.5 cm wide) were cut from the same muscles that were used in sensory evaluation. The muscles tested were biceps femoris, semimembranosus, and quadriceps femoris muscles. The slices were cut across the muscles in a manner that maximized the number of measurements per strip. Texture measurements were made on a TA-XT2 Texture Analyzer with a Warner-Bratzler attachment (Texture Technologies Corp., Scarsdale, NY). The force in grams required to cut through the sample was measured every 2 cm. The value for the highest peak produced was recorded for each cut. The test speed was 5.0 mm per sec and the test distance was 30 mm. The force threshold was set to 20 g.

Volatiles Content

The volatiles content of the country hams was determined using Solid Phase Micro-Extraction (SPME). Uncooked samples of the hams used in the sensory evaluation panels were stored under refrigeration until just prior to testing on the same morning. The samples were cooked in the same manner as the samples used in the

user panel. The cooked samples were cut into pieces 1.5 cm or less long. The samples were frozen in liquid nitrogen and powdered using a Waring Blendor® (Model 1120, New Hartford, CT).

A 1-g sample was measured into a 4-mL sample vial that was sealed with a pre-punctured PTFE silicone septa (Supelco, Inc. Bellefonte, PA). The sample was set on a SPME sampling stand and heated on a Corning hot plate (model PC-400/410/420, Corning, Inc., Corning, NY) set at level 2. The temperature was regulated to maintain a temperature of 45-47 °C. This temperature was selected because it is just above the actual temperature of the human mouth and high enough to allow release of the volatiles for absorption onto the fiber. Therefore, the same volatiles that the sensory panelists picked up should also be absorbed onto the fiber. The sample was exposed for 15 min to a 50/30 µm Divinylbenzene/ Carboxen/ Polydimethylsiloxane fiber (Supelco, Inc., Bellefonte, PA). These conditions are based on previous research that determined the best conditions for SPME in dry-cured ham (Ruiz and others 1998a).

The volatiles were desorbed onto a GC-MS for 10 min (GC-17A, GCMS QP5000, Shimadzu Kyoto, Japan). The injection port was fit with a smaller glass liner for SPME fibers and had a temperature of 250°C. The injection and interface temperatures were 260°C. The analysis was run at an initial column temperature of 40 °C for 10 min during which the SPME fiber was desorbed. The temperature then was programmed at a rate of 7 °C per min to an end temperature of 250 °C. The end temperature was held for 5 min. A TXI-5 (0.25µm thick) capillary column with 0.25 mm diameter by 30 m length was used (Restek Corp. Bellefonte, PA). The run was performed in a splitless mode. The carrier gas was helium. It flowed at a rate of 1.2 mL/min and a linear velocity of 39.5 cm/sec. The column inlet pressure was 63.21 Kpa.

The mass spectrum was collected in a M/Z range of 33-350 and was started 2.2 min after injection. The analysis was run for both qualitative and quantitative purposes.

A blank was run before each sample. The SPME needle was placed in the injection port at 250 °C and held for 30 min without exposing the fiber. Then, the fiber was exposed and desorbed onto the column for 10 min. The sample analysis procedures previously described were used. This allowed for identification of any foreign compounds coming off the fiber itself.

The mass spectra of the volatiles found in each sample were compared with the library of the system to tentatively identify the compounds. Standards were run on the GC-MS under the same conditions to positively identify some of the compounds. The retention times and the mass spectra of the sample compounds and the standards were compared in order to make positive identification of the volatile components.

Statistical Analysis

The results of the consumer survey, user panel, volunteer panel (expect preference results), oxidation, shear, cooking loss and volatiles were analyzed using SAS (Cary, NC). The PROC FREQ procedure was used in analysis of the consumer survey and volunteer panel just right scales, identification question, and familiarity question. The PROC GLM procedure was used for the other results. Least-squares means were also determined for the genetic groups, processing days, and genetic group and processing day interactions. Analysis of variance tables can be seen the appendix (p.116-119). The paired preference results from the volunteer panel were analyzed using statistical table from Roessler and others (1978). A p-value of 0.05 was used as the criterion for significant differences:

Chapter 4

Results and Discussion

Consumer Survey

Panel Demographics

A total of 27 panelists participated in the user panel. There were 10 males and 17 females. In terms of consumption, 6 panelists ate country ham once every 2-3 wk or more often. There were 7 panelists who consumed it every 6 mo and 7 who consumed it once every 2-3 mo. The remaining panelists ate country ham once a year.

Appearance

The consumer survey showed definite trends for the terms consumers of country ham associate with the product. The results for the questions about appearance are in Table 5. Individuals mainly described country ham in their own words as being red and marbled; both of which they liked in the product. When given the list of descriptors, respondents felt that the terms red, marbled, bright, yellow-fat, oily (fat), dry (fat), and brown (fat) described the appearance of the ham. Based upon this list, red color (pale to bright) was selected for use in the sensory user panel. The terms dealing with fat were not used because the terms apply primarily to the raw fat of the product. These attributes are not observable in the cooked product.

Aroma

The second area of interest in the consumer survey was aroma. The results of the survey are in Table 6. Meaty, pork, and smoky were the main terms that the

Table 5 - Number of people who described the appearance of country ham, response with prompting with a list of terms from literature, and their opinion of the attribute in the product ^a

Descriptor	Own words	Response to literature term	Opinion of attribute	
			Like	Dislike
Red	11	16	10	0
Marbled	7	14	4	2
Pale	1	7	1	0
Brown-fat	1	14	0	1
Bright	0	12	0	0
Yellow-fat	0	10	0	1
Pink-fat	0	6	0	0
Oily-fat	0	16	0	1
Dry-fat	0	14	0	1

^a Number of people surveyed = 27.

Table 6 - Number of people who described the aroma of country ham, responses with prompting with a list of terms from literature, and their opinion of the attribute in the product ^a

Descriptor	Own words	Response to literature term	Opinion of attribute	
			Like	Dislike
Meaty	8	24	8	0
Pork	7	24	1	0
Smoky	6	21	5	0
Cured	3	25	1	0
Nutty	2	11	1	0
Strong	2	21	1	0
Pungent	2	11	0	0
Musty	2	8	1	2
Fresh meat	1	8	0	1
Fresh fat	1	6	0	0
Rancid	1	9	1	0
Spicy	1	8	1	0
Mushroom	0	2	0	0
Weak	0	1	0	0
Barnyard	0	3	0	0
Hay-like	0	1	0	1
Acorn	0	1	0	0

^a Number of people surveyed = 27.

panelists used to describe the aroma in their own words and found desirable. The consumers recognized nutty, meaty, pork, rancid, strong, cured, smoky and pungent as making up the aroma from the list of terms. Based upon this list, overall aroma, pork aroma, and rancid aroma intensities were selected for use in the sensory user panels. Meaty was combined with pork since it is assumed to be covered by the term pork. Strong was used through overall aroma intensity. Rancid was included because it can be an effect of oxidation, which was also measured in this experiment. Cured was omitted because of the lack of a standard definition among panelists. Smoky was not used because the product was not smoked.

Taste / Flavor

The flavor of country ham made up the third portion of the consumer survey. The results are in Table 7. The majority of the panelists responded salty when asked to describe country ham in their own words. Pork was also mentioned by the individuals to describe the flavor. A few panelists did mention sweet, intense, smoky, and rancid. With the exception of rancid, the consumers found these to be desirable flavors in country hams. In response to the list of terms from literature, the individuals indicated that salty, pungent, dry-cured flavor, sweet, intense, after-taste, brown spice, smoky, and pork were terms that they associated with the flavor of country ham. Overall flavor intensity, salty taste, sweet taste, pork flavor, rancid flavor, and dry-cured flavor were selected as terms for the user sensory evaluation panels. Pungent was included in overall flavor intensity. Brown spice was not used because of difficulty in clearly defining the term. Smoky was omitted since the hams had not been smoked. Rancid

Table 7 - Number of people who described the taste/flavor of country ham, responses with prompting with a list of terms from literature, and their opinion of the attribute in the product ^a

Descriptor	Own Words	Opinion of attribute		Response to literature term
		Like	Dislike	
Salty	25	21	1	24
Pork	9	5	0	25
Sweet	6	5	0	14
Intense	6	3	1	23
Smoky	5	4	0	21
Rancid	3	0	1	6
Pungent	2	1	1	15
Dry cured flavor	2	2	0	23
Fresh meat	2	2	0	7
Mushroom	1	0	0	1
Tart	1	0	1	2
Acid	0	0	0	6
Bitter	0	0	0	3
Butter	0	0	0	3
Hazel nut	0	0	0	2
Off-flavors	0	0	1	9
Fruity	0	0	0	1
Stale	0	0	0	6
After-taste	0	0	0	20
Musty	0	0	1	11
Barnyard	0	0	0	2
Hay-like	0	0	0	0
Brown spice	0	0	0	13
Cheesy	0	0	0	1

^a Number of people surveyed = 27.

was included since differences in oxidation of the fat, and therefore, differences in rancidity, were expected in the hams.

Texture

The final area of the consumer survey dealt with texture. The results are in Table 8. The panelists used tender, chewy, dry, and fibrous as words to describe country ham. Most found these characteristics with the exception of fibrous to be desirable. The individuals overall found all of the terms from literature to be descriptive of the texture of country ham. The terms listed and indicated by the panelists to be characteristic of country ham are in Table 8. The terms were divided into the pairs of dry/juicy, tough/tender, and hard/soft for use in the user sensory panel. Chewy was included as a part of tough. Firm was considered to be a part of hard. Fibrous was not included because the ham slices were too thin to really evaluate it.

Sensory Evaluation-User Panel

Panel Demographics

A total of 72 panelists participated in the user panel; 44 males and 28 females. The ages of the panelists ranged from under 20 to 60-69. The majority of the panelists were in the 20-29 age group (29). Other age groups with large numbers of panelists were 40-49 (10) and 50-59 (14). In terms of consumption, 20 panelists ate country ham once every 2-3 wk and 18 ate it once every 2-3 mo. A total of 14 in both groups of panelists ate country ham 6 mo or once a mo.

Table 8 - Number of people that described the texture of country ham, response with prompting with a list of terms from literature, and their opinion of the attribute in the product ^a

Descriptor	Own words	Opinion of attribute		Response to literature term
		Like	Dislike	
Tender	6	6	1	14
Juicy	2	2	0	12
Chewy	11	7	1	21
Dry	7	1	2	19
Firm	2	2	0	25
Fibrous	5	3	4	18
Hard	2	1	2	13

^a Number of people surveyed = 27.

Genetic Group Comparisons

A panel of country ham eaters evaluated the samples of ham using a 15-intensity scale. The results were analyzed to determine if differences in genetic groups existed. The mean values are reported in Table 9. There were no differences for any of the attributes between the two genetic groups. The cure process seems to void out any potential differences between product from Duroc and Market Mix pigs. The flavor intensity of the cured product is so great that differences in flavor acceptability attributed to genetic group are no longer apparent. The lack of differences in overall acceptability is consistent with other research findings. Other researchers found no difference in overall acceptability between fresh meat from Durocs and other breeds even when differences in sensory characteristics such as flavor intensity were present (Martel and others 1988; Edwards and others 1992). However, in specific comparisons between meat from Durocs and Yorkshires and Durocs with Landrace, Large White, and Belgian Landrace the meat from the Durocs had a higher overall acceptability over all of the others with the exception of Large White (Enfält and others 1997; Oliver and others 1994). These conflicting results seem to indicate that factors other than just genetic group impact the quality perception of the product. Variations in processing and preparation methods may be the source for some of the conflicting results.

Processing Day Comparisons

The results of the same panel were also examined for differences between the processing days. The results are in Table 10. There were no differences between the means for any attribute except saltiness and dryness. The hams processed on day 1

Table 9 – Least-squares mean values for sensory attributes for 2 genetic groups in the evaluation of country ham in a user panel ^a

Attribute	Scale anchors (1/15)	Duroc	Market mix
Overall flavor	dislike extremely/ like extremely ^b	9.3	9.7
Red color	pale / dark	8.4	8.0
Overall aroma	none / intense	9.1	9.1
Pork aroma	none / intense	8.2	8.1
Rancid aroma	none / intense	4.1	4.0
Overall flavor intensity	none / intense	9.9	9.9
Salty taste	none / intense	9.7	9.7
Sweet taste	none / intense	4.8	4.6
Pork flavor	none / intense	8.6	8.2
Dry-cure flavor	none / intense	8.1	8.3
Rancid flavor	none / intense	4.3	3.9
Texture	extremely dry / extremely juicy	9.4	9.3
Texture ^c	extremely tough / extremely tender	8.7	8.8
Texture ^c	extremely hard / extremely soft	8.4	8.6

^a The means in a row are not significantly different ($p>0.05$).

^b 72 panelists across 2 processing days.

^c Significant interactions reported in Table 11.

Table 10 – Least-squares mean sensory scores for processing day differences in country ham samples used in a user panel ^a

Attribute	Scale anchors (1/15)	Day 1	Day 2
Overall flavor	dislike extremely/ like extremely ^b	9.5	9.5
Red color	pale / dark	8.2	8.3
Overall aroma	none / intense	9.1	9.1
Pork aroma	none / intense	8.3	8.0
Rancid aroma	none / intense	3.9	4.2
Overall flavor intensity	none / intense	10.1	9.7
Salty taste	none / intense	10.0 a	9.4b
Sweet taste	none / intense	4.8	4.6
Pork flavor	none / intense	8.6	8.2
Dry-cure flavor	none / intense	8.0	8.4
Rancid flavor	none / intense	4.1	4.2
Texture	extremely dry / extremely juicy	9.6a	9.1b
Texture ^c	extremely tough / extremely tender	8.8	8.6
Texture ^c	extremely hard / extremely soft	8.6	8.5

^a Means in a row with differing numbers are significantly different ($p < 0.05$).

^b 72 panelists across 2 breed groups.

^c Significant interactions reported in Table 11.

were perceived as saltier than those processed on day 2 ($p < 0.05$). This perceived difference was backed by an actual difference in salt content between the hams of the 2 processing days. The average salt content of the hams processed on day 1 was 4.9% and it was 3.9% in the hams processed on day 2 (Ingle 2001). These results are parallel to differences in dryness of the samples. The samples processed on the first day were drier than those processed on the second day. This is expected from the higher salt content of the hams from day 1 (Ingle 2001). There would be a greater feeling of dryness in the mouth from the high salt causing the hams to be perceived as drier. The resulting values reflected the inexactness of the processing method.

Genetic Group and Processing Day Interactions

The results were analyzed for genetic group and day interactions (Table 11). There were no significant interactions for any of the attribute means except hardness and toughness. The samples from Duroc day 2 and Market Mix day 1 were significantly softer than those from Market Mix day 2 and Duroc day 1 ($p < 0.05$). This difference may be attributable to differences in salt content and slight differences in the genetic groups (Tables 2-3, p 27). The samples from Duroc day 1 and Market Mix day 2 were less tender than samples from Market Mix day 1 ($p < 0.05$).

Table 11 - Least-squares interaction means for hedonic and intensity scores for country ham samples from different genetic groups and processing days in a user panel ^a

Attribute	Scale anchors (1/15)	Duroc		Market Mix	
		Day 1	Day 2	Day1	Day 2
Overall	dislike extremely/ like extremely ^b	9.8	9.2	9.6	9.5
Red color	pale / dark	8.1	8.4	8.0	8.4
Overall aroma intensity	none / intense	9.1	9.0	9.0	9.1
Pork aroma	none / intense	8.0	8.0	8.2	8.4
Rancid aroma	none / intense	4.1	4.2	3.9	3.9
Overall flavor intensity	none / intense	9.7	9.8	10.1	10.0
Salty taste	none / intense	9.5	9.3	9.9	10.1
Sweet taste	none / intense	4.5	4.8	4.8	4.7
Pork taste	none / intense	8.3	8.5	8.4	8.7
Dry cured flavor	none / intense	8.5	8.3	8.1	7.9
Rancid flavor	none / intense	3.9	4.5	4.0	4.2
Texture	extremely dry / extremely juicy	8.9	9.2	9.7	9.6
Texture	extremely tough / extremely tender	8.4b	8.9ab	9.3a	8.4b
Texture	extremely hard / extremely soft	8.0a	8.9b	9.2b	7.9a

^a Least-squares means with different letters in rows are significantly different ($p < 0.05$).

^b 72 panelists.

Ideal Results

The mean scores for the evaluation of an ideal country ham slice are in Table 12. The values are above the mid-point on the scale for red color, aroma intensity, pork aroma, saltiness, pork flavor, and dry-cured flavor. The values are low for rancid aroma and flavor. Sweetness had an ideal level in the middle. These results were expected. The attributes that had high values are those that are commonly identified as attributes that are characteristic of the product and desirable in it. Those with low values are less commonly found in high quality country ham and those that are almost always considered to be undesirable. The sweetness level is intermediate. This has many explanations. Not all country hams have high levels of sweetness, therefore it is not always readily apparent.

Genetic Group Comparisons to the Ideal

The deviations of the sample means from the ideal mean value were used to analyze the results of the user panel. The mean deviations from the ideal scores for the two genetic groups are in Table 12. There were no significant differences in the sample deviations from the ideal ($p > 0.05$). Thus, the samples from the 2 genetic groups were equally different from the ideal. The lack of differences in the sensory perception of the hams from the two genetic groups may be potentially attributed to the nature of the product. The extreme saltiness of the product may have masked flavor differences in these products.

Table 12 – Least-squares mean deviations from the ideal for sensory attributes for the two genetic groups used in the user panel ^a

Attribute	Scale anchors (1/15)	Ideal ^b	Duroc	Market mix
Red color	pale / dark	9.9	1.42	1.80
Aroma	none / intense	11.0	1.96	1.93
Pork aroma	none / intense	8.6	-0.43	0.48
Rancid aroma	none / intense	3.2	-0.89	-0.87
Overall flavor intensity	none / intense	11.5	1.59	1.56
Salt taste	none / intense	9.1	-0.57	-0.54
Sweet taste	none / intense	6.2	1.41	1.51
Pork flavor	none / intense	9.0	0.44	0.83
Dry-cure flavor	none / intense	9.2	1.06	0.94
Rancid flavor	none / intense	3.1	-1.24	-0.82
Texture	extremely dry / extremely juicy	8.9	-0.48	-0.37
Texture ^c	extremely tough / extremely tender	8.5	-0.18	-0.35
Texture ^c	extremely hard / extremely soft	9.2	0.77	0.56

^a No differences ($p>0.05$) among means were found.

^b 72 panelists across 2 genetic groups.

^c Significant interactions reported in Table 14.

Processing Day Comparisons to the Ideal

There were differences found in some sensory attributes between the 2 processing days. The mean deviations for the sensory attributes for the 2 processing days and the mean ideal values are in Table 13. Most of the attributes were not found to be significantly different. The dry cured flavor of day 1 had a significantly higher deviation from the ideal than day 2 ($p < 0.05$). This may be attributable to differences in the processing of the hams. The intensity of the dry cured flavor was lower than the ideal. The hams processed on the second day may not have received as much of the cure ingredients as those processed on the first. Other differences in the raw product and in processing may also be sources of this variation. The dryness and the hardness also differed between the two processing days ($p < 0.05$). The mean score of dryness of the hams from day 1 had a deviation, which was significantly higher than that of day 2. The hams were drier than the consumer "ideal".

Genetic Group and Processing Day Interactions- Comparisons to the Ideal

There were 2 significant interactions among the genetic groups and days for textural properties. The deviations of the mean scores from the ideal and the mean ideal values are in Table 14. The deviation from the mean score for hardness for Market Mix day 1 was different from that of Market Mix day 2 ($p < 0.05$). The mean value for Duroc day 1 and day 2 did not have deviations that were significantly different from the others ($p > 0.05$). The differences are most likely due to the differences that were observed in processing days. The lack of difference between the genetic groups most likely balanced out some of the day differences. Perhaps the Duroc had a slightly (but not significantly) less tender texture that evened out some of the processing day

Table 13 – Least-squares mean deviations for attribute scores for processing days in the user panel ^a

Attribute	Scale anchors (1/15)	Ideal ^b	Day 1	Day 2
Red color	pale / dark	9.9	1.65	1.58
Aroma	none / intense	11.0	2.19	1.70
Pork aroma	none / intense	8.6	0.32	0.58
Rancid aroma	none / intense	3.2	-0.76	-1.00
Overall flavor intensity	none / intense	11.5	1.61	1.54
Salt taste	none / intense	9.1	-0.63	-0.49
Sweet taste	none / intense	6.2	1.59	1.33
Pork flavor	none / intense	9.0	0.71	0.56
Dry-cure flavor	none / intense	9.2	1.60a	0.40b
Rancid flavor	none / intense	3.1	-0.93	-1.13
Texture	extremely dry / extremely juicy	8.9	-1.03a	0.19b
Texture ^c	extremely tough / extremely tender	8.5	-0.53a	-0.01b
Texture ^c	extremely hard / extremely soft	9.2	0.50	0.83

^a Means in the same rows with differing letters are significantly different ($p < 0.05$).

^b 72 panelists across 2 genetic groups.

^c Significant interactions reported in Table 14.

Table 14 –Least-squares mean deviations from the ideal for genetic group and day interactions for country ham samples in the user panel ^a

Attribute ^b	Ideal	Duroc		Market mix	
		Day 1	Day 2	Day 1	Day 2
Texture-Toughness	9.2	1.16ab	0.39bc	-0.17c	1.28a
Texture-Hardness	8.5	-0.26ab	0.11ab	-0.95b	0.25a

^a Means in the same rows with differing letters are significantly different ($p < 0.05$).

^b 1=extremely tough or hard; 15=extremely tender or soft; 72 panelists.

differences. The deviation from the mean score for toughness for Market Mix day 1 was different from that of Market Mix day 2 and Duroc day 1 ($p < 0.05$). The deviation of the mean for Duroc day 2 differed from Market mix day 2 ($p < 0.05$), but was the same as Market Mix day 1 and Duroc day 1 ($p > 0.05$).

Sensory Evaluation-Volunteer Panel

The hams were also evaluated in an volunteer panel in which people who did not normally eat country ham were allowed to taste in addition to those who did. This allowed for a more general and broad opinion of the hams to be obtained. Also, the volunteer panel was used because someone who was not a country ham user had a greater potential to pick up differences than someone who was accustomed to the product. A variety of scales were used including hedonic, just right, paired preference, and identification.

Panel Demographics

A total of 60 panelists participated in the panel. Of these, 19 were males and 41 were females. The ages of the panelists ranged from under 20 to 60-69. The majority of the panelists (29) were in the 20-29 age group, and the second largest age group was 40-49 (13). In terms of consumption, the largest group (19) ate ham once every 2-3 mo. There were also large groups (13) that ate ham every 2-3 wk and once every 6 mo (11). When asked how often they eat the type of ham presented to them in the panel (country ham), the largest group of consumers (18) ate it once every 2-3 mo. A

large group ate it once every 6 mo (11), and another large group ate it less than once a year (10).

Hedonic Results-Genetic Groups Comparison

The panelists did show one major difference in their evaluation of the country ham samples. The results are in Table 15. The mean overall score for the unknown Market Mix was significantly higher than the mean score given to the Duroc samples ($p < 0.05$). In terms of liking the samples, 80% of the panelists liked the Market Mix samples, while only 70% of the panelists liked the Duroc samples. There are no other differences between the liking of the sample attributes that can be used to explain this difference. The aroma, appearance, flavor, and texture of both products were liked equally ($p > 0.05$).

The means of these scores are all in the range of 6-7 for the hedonic scales, meaning that the panelists like the attributes of the product slightly to somewhat. The scores may have been lowered by people who do not consume country ham and are not accustomed to the uniqueness of the product characteristics but were included in the evaluation. These individuals may have rated the product lower than individuals who are used to and regularly consume the product.

Hedonic Results-Processing Day Comparison

When the results of the panel were analyzed by processing day, several differences existed. The results are in Table 16. The hams from the first processing day were liked more than those from the second day ($p < 0.05$). The other differences

Table 15 - Least-squares mean hedonic scores
for sensory evaluation of country hams of
different genetic groups in the volunteer panel ^a

Attributes ^b	Genetic group	
	Duroc	Market mix
Overall	6.2a	6.8b
Aroma	6.6	7.0
Appearance	6.5	6.6
Flavor	6.4	6.9
Texture ^c	6.0	6.5

^a Means in a row with like letters are not significantly different ($p>0.05$); ^b 1- dislike extremely and 9- like extremely; n= 60 panelists (30 per processing day).

^c Significant interactions reported in Table 17.

Table 16 - Least-squares mean hedonic scores for sensory evaluation of country hams from 2 processing days in the volunteer panel ^a

Attribute ^b	Processing day	
	Day 1	Day 2
Overall	7.2a	5.8b
Aroma	7.2a	6.4b
Appearance	7.2a	6.0b
Flavor	7.4a	6.0b
Texture ^c	6.9a	5.6b

^a Means with like letters are not significantly different ($p>0.05$)

^b 1- dislike extremely and 9- like extremely; n= 60 panelists (30 per day).

^c Significant interactions reported in Table 17.

may be used to explain this difference. The panelists liked the aroma, appearance, flavor and texture of the samples from the first processing day better than those of the second day ($p<0.05$).

The average scores of the samples on the 2 processing days (5.6-7.4) had a greater range than the scores for the genetic groups (6.2-7.0). These mean scores equate to the opinions of the panelists ranging from neither like nor dislike the product to like the product somewhat. Overall, the low scores may be attributed to the inclusion of non-country ham consumers in the panel as discussed previously. The lower range in the processing day results for day 2 may be related to the lower perceived level of salt that will be shown in the just right scale results.

Hedonic Results-Genetic Group and Processing Day Interactions

There was one genetic group and processing day interaction. The results are in Table 17. The difference in texture that was found between processing days was dependent on the interactions with genetic group. The mean texture scores on processing day 1 were the same for the 2 genetic groups ($p>0.05$). The mean scores of both processing days for Duroc samples differed ($p<0.05$). The texture of Market Mix day 1 samples was liked less than the Duroc day 2 samples ($p<0.05$). The Market Mix day 2 had a mean texture score that was lower than those of all the other Duroc combinations ($p<0.05$).

Table 17 – Least-squares mean scores for genetic group and processing day interactions for sensory evaluation of ham samples in the volunteer panel. ^a

Attribute ^b	Duroc		Market mix	
	Day 1	Day 2	Day 1	Day 2
Overall	6.8	5.6	7.6	6.0
Aroma	6.8	6.3	7.6	6.4
Appearance	7.1	6.0	7.2	6.0
Flavor	6.9	5.9	7.8	6.1
Texture	5.9a	5.0c	6.8ab	6.1b

^a Means with like letters are not significantly different ($p > 0.05$).

^b 1- dislike extremely and 9- like extremely; n= 30 panelists.

Just Right Scale Results

The results of the just right portion (Appendix p.110-113) of the sensory tests are in Tables 18-20. Table 18 has the frequency of responses for the question of aroma intensity for the 4 treatment combinations. The majority of the responses were that the aroma intensity was just right. For the samples from both genetic groups, the remaining results are skewed towards the level being too little. Any differences may be attributed to the differences in volatiles content that will be discussed later.

The just right scale results regarding the flavor intensity are in Table 18. The majority of the responses for all treatment combinations were just right. The remaining responses are mainly in the too intense side of the scale. This potentially is from the inclusion of panelists that are not frequent consumers of country ham or do not eat it. The characteristic flavor may be overwhelming to them.

The just right results regarding salt intensity are in Table 18. The results are divided between just right and slightly too much salt in general. The number of responses for slightly too much are slightly larger than that for just right. The remaining responses are skewed towards the much too much answer. These responses may be coming from those who do not normally consume country ham. The Market Mix day 2 samples had higher numbers of much too much salt responses, this is not reflective of the actual salt content (Ingle 2001).

Sweetness level was also evaluated using the just right scales. The results are reported in Table 18. The majority of the responses were just right. The remaining results are skewed towards too little sweetness. Many individuals stated that the samples had slightly too little sweetness. Many individuals in this area of the country

Table 18 - Frequency of responses for just right question about ham aroma, flavor, salt and sweetness intensities for country hams from 2 genetic groups processed on 2 days by the volunteer sensory panels ^a

Attribute	Response	Duroc		Market mix	
		Day 1	Day 2	Day 1	Day 2
Aroma intensity	Much too intense	1	1	0	0
	Slightly too intense	6	3	1	5
	Just right	18	19	23	16
	Slightly too little	4	4	5	5
	Much too little	1	3	1	4
Flavor intensity	Much too intense	2	2	0	1
	Slightly too intense	10	7	6	14
	Just right	14	16	21	12
	Slightly too little	4	5	3	3
	Much too little	0	0	0	0
Salt intensity	Much too much salt	7	3	0	9
	Slightly too much salt	11	15	12	13
	Just right	11	11	13	6
	Slightly too little salt	1	0	5	1
	Much too little salt	0	1	0	1
Sweetness Intensity	Much too much sweet	0	0	0	0
	Slightly too much sweet	1	2	3	3
	Just right	15	17	21	13
	Slightly too little sweet	8	9	4	10
	Much too little sweet	6	2	1	4

^a Number of panelists = 30.

are accustomed to a sweeter, sugar-cured country ham. The intensity of the salt masking the sweetness may also be playing a role.

The color intensity was also examined. The frequencies of responses are in Table 19. With the exception of samples from Duroc day 2, the majority of the results are just right with the remaining results being basically normally distributed. The large number of too dark responses for Duroc may serve as explanation of the overall differences in acceptability that the panelists found.

Panelists rated the moistness of the ham samples using the just right scale. The frequency of responses is in Table 20. Most panelists rated the moistness as just right. The remaining responses were skewed towards too dry. The product may have been slightly drier than some consumers are used to since a dry heat method was used for cooking. There is wide variation in how people cook country ham and many people may use moist heat methods as instructed on packages of country ham. The responses may also be from people who eat fresh ham more often, and therefore, are used to (and like) a slightly more moist product. There were greater numbers of slightly too dry and much too dry for the samples processed on day 2 for both genetic groups.

The final question of just right scales involved the tenderness of the samples. The results are in Table 20. The responses were mainly divided between just right and slightly too tough. The too tough responses may be coming partially from the 21 panelists who eat country ham once every 6 mo or less than once a year. It is tougher meat than a traditional baked ham.

Table 19 - Frequency of responses for just right question about ham color intensity for country hams from 2 genetic groups processed on 2 days by the volunteer sensory panels ^a

Response	Duroc		Market mix	
	Day 1	Day 2	Day 1	Day 2
Much too dark	0	3	0	0
Slightly too dark	6	6	4	6
Just right	18	13	22	17
Slightly too pale	6	7	4	7
Much too pale	0	1	0	0

^a Number of panelists = 30.

Table 20 - Frequency of responses for just right question about moistness and tenderness in country hams from 2 genetic groups processed on 2 days by the volunteer sensory panels ^a

Attribute	Response	Duroc		Market mix	
		Day 1	Day 2	Day 1	Day 2
Moistness	Much too juicy	0	0	0	0
	Slightly too juicy	1	1	1	2
	Just right	24	13	22	18
	Slightly too dry	5	15	7	9
	Much too dry	0	1	0	1
Tenderness	Much too tender	0	0	0	1
	Slightly too tender	0	2	0	1
	Just right	20	6	15	16
	Slightly too tough	10	19	15	11
	Much too tough	0	3	0	1

^a Number of panelists = 30.

Paired Preference Results

A paired preference test was also done as part of this panel as can be seen on the sample scorecard in the appendix (p 114). The results are in Table 21. There were no preferences between the samples in terms of genetic group. One of them had close to the required 32/48 panelists preferring one sample to the other ($p=0.1110$, Roessler and others 1978). The samples from the Market Mix were close to being preferred over those from the Durocs. This corresponds to a higher overall liking score given to the samples from the Market Mix. Panelists (12) who did not indicate a preference for one sample or the other were not included in determining the number of panelists required for preference.

Ham Identification Results

The panelists were asked to identify the type of ham that they thought that they were given and then indicate with which types of ham they were familiar. The results of these questions are in Table 22. The majority of the panelists (60%) identified it as country ham. Another large group thought that it was salt-cured ham. A few chose smoked, cured, sugar-cured ham, dry-cured ham, and baked ham.

Ham Familiarity Results

The results of the types of ham that the panelists were familiar with go along with the identification choices. The majority of the panelists was familiar with country ham, baked ham, sugar-cured ham, and smoked ham. Large groups also had

Table 21 - Preference totals for ham samples used in the volunteer sensory panel ^a

Factor	Category	Number of panelists expressing preference	P-value
Genetic group	Duroc	18	0.1110
	Market Mix	30	

^a Number needed for preference 32/48 ($p=0.05$) (Roessler and others 1978).

Table 22 - Results of survey of potential type of ham used in the open panel and type of hams with which the panelists were familiar. ^a

Type of ham	Identity of sample	Familiar with
Country ham	36	48
Smoked ham	3	35
Cured ham	3	20
Salt cured ham	27	26
Sugar cured ham	1	37
Dry cured ham	4	9
Wet cured ham	0	5
Baked ham	1	46
City ham	0	9
Fresh ham	0	21
Smithfield ham	0	11
Virginia ham	0	15

^a Number of panelists =60.

knowledge of cured ham, fresh ham, salt-cured ham, and Virginia ham. At least a portion of the panelists was familiar with all types of ham that were listed. Of the terms given, the 4 that could truly be used to describe the ham samples used in the study are country ham, salt-cured ham, cured ham, and dry-cured ham. The samples used fully meet the definitions of these types of hams. There are some others that the samples were close to such as sugar-cured ham and Smithfield ham, but they really did not meet the full meaning of the terms. The results show that the panelists were really only familiar enough with 2 of these 4 names to use them. Cured ham and dry-cured ham are more technical terms that a common consumer most likely would not know. The results of the familiarity question did show that the panelists had enough knowledge of different types of hams to be able to eliminate them as choices for identification. The only potential exception to this is the cured ham term. Panelists indicated that they were familiar with it but few used it to describe the ham sample.

Oxidation-Thiobarbituric Acid Analysis

Oxidation was measured on the ham samples, because differences in marbling and the outer fat layer were observed in visual examination of the slices of ham. Also, many volatile compounds in country hams have been shown to be products of lipid oxidation (Berdague and others 1993). The oxidation measurements showed no difference between the hams from the two genetic groups ($p>0.05$). The mean TBA values were 0.90 and 1.01 for the Market Mix and Duroc respectively. The mean of 1.2 for the second day was significantly higher than the mean of 0.7 for the first day ($p<0.05$). This is important because higher oxidation levels have been shown to significantly lower flavor scores in dry-cured hams (Olson and Rust 1973). They have

also been shown to be negatively correlated with overall hedonic scores (Baker 1976). There seems to have been differences in processing that have caused the differences between the processing days. The application of the cure ingredients may have been different, and therefore, the preservation of the hams different. There were no differences between the panel days or for the genetic group and day interactions ($p>0.05$). The means for genetic group and processing day interactions are in Table 23. The values for TBA agreed with other researchers who found the TBA value of cured meat to be no higher than 1.5 (Younathan and Watts 1959). The values are also lower than the mean TBA value of 3.75 reported by Baker (1976).

The TBA values were also compared for the 6 d of user sensory panels of the experiment. The mean values are in Table 24. There were no differences in the values between the panel days ($p>0.05$). The days also represent additional time of aging since the panels were spread out over a 2-mo period. The hams used on the final panel day were aged under refrigeration in storage for 2-mo longer than those used in the first day of panel. These results of no difference over time are consistent with the finds of Younathan and Watts (1959). The researchers found that curing salts and antioxidants restricted oxidation and prevented changes in TBA values over a 7 d period at refrigerator temperatures.

Cook Loss

The amount of loss during cooking and after a 20-min draining period was also determined. The mean values for both time periods are in Table 25. There were no differences in the average weight losses in the samples when the data were analyzed

Table 23 – Least-squares mean oxidation values (TBA numbers) for genetic group and day interactions for country ham samples ^a

Genetic group	Processing day	TBA value (mg malonaldehyde/Kg meat)
Duroc	1	0.75
	2	1.28
Market mix	1	0.73
	2	1.07

^a No differences among means ($p>0.05$); $n=6$ hams.

Table 24 – Least-squares mean TBA values as oxidation measurements for ham samples from six experimental days of user sensory panels ^a

Day	TBA number (mg malonaldehyde/Kg meat)
1	0.80
2	0.94
3	0.95
4	0.96
5	1.22
6	0.87

^a No differences among means ($p>0.05$); $n=48$ (8 per day).

Table 25 - Least -squares mean percentage cook loss measured before and after draining for ham samples used in the user panel ^{ab}

Variable	Samples	Cook loss (%)	Overall loss after draining (%)
Genetic group	Duroc	6.6	11.7
	Market mix	7.1	12.4
Processing day	Day 1	6.7	12.0
	Day 2	7.0	12.0

^a No differences among means ($p>0.05$). ^b $n=12$.

by genetic group and by processing day ($p>0.05$). There were also no differences in the overall loss after draining between the genetic groups and days.

The data were also analyzed for any interaction differences for the cook loss and overall loss after draining. The mean values for each treatment combination are in Table 26. There were no differences among the treatment combinations for either cook loss or overall loss after draining.

Texture-Shear Values

Shear values were taken on samples of the 24 hams used in the user panels. There were no differences in mean shear values between the two genetic groups ($p>0.05$). The average means across all muscles were 8241 g for Market Mix samples and 8339 g for Duroc samples. The shear value for processing day 1 of 8727 g was significantly higher than that of 7853 g for processing day 2 ($p<0.0001$). The difference may be attributable to a difference in salt content. The hams from processing day 1 had a salt content of 4.9% which was significantly higher than the value of 3.9% for processing day 2 (Ingle 2001). The additional salt may have also inhibited some of the enzymes that were working to break down the proteins in the ham, since there are no differences in final moisture content (Ingle 2001). Cure ingredients have been shown to impact the activity of enzymes in dry-cured ham (Toldra and others 1997; Toldra and Flores 1998). Several of the enzymes actively influencing the texture of dry-cured ham are inhibited by salt (Toldra and others 1997). Salt content has been shown to impact textural perceptions of dry-cured ham and thus, influence quality perception (Guerrero and others 1999).

Table 26 - Least-squares mean percentage cook loss measured before and after draining for breed and processing day interactions for samples of ham used in user panels ^a

Samples	Cook loss (%)	Overall loss after draining (%)
Duroc day 1	6.5	11.6
Duroc day 2	6.8	11.8
Market mix day 1	6.9	12.4
Market mix day2	7.3	12.2

^a No differences among means ($p>0.05$).

Interactions among the genetic groups and day combinations were also examined. There were no differences among the treatment combinations for shear values.

The shear values of the different muscles and muscle groups used in the consumer panel were also compared. The muscle groups were biceps femoris, semimembranosus and quadriceps femoris (quad). The quadriceps femoris was a group of muscle and was divided by muscle into 3 groups (quad 1, 2, and 3) for texture analysis. The mean values for the muscle groups are in Table 27. Several differences were present. The only muscles that had shear values that were not significantly different were semimembranosus and quad group 2 ($p > 0.05$). All other muscle groups had shear values that were significantly different from each other ($p < 0.05$). These differences show the large variation in texture that is present in a single slice of ham. The shear force varies between the muscles in the slices. The slice location, therefore, could influence the perception of textural properties. Thus, these results provide justification for the control of the samples given to panelists.

Volatiles Content

A total of 61 compounds was tentatively identified in the volatiles of the country ham samples. Of these, 26 were positively identified. The compounds along with their retention times and a comparison of the mean peak areas (an indicator of concentration) for the 2 genetic groups are in Table 28. There were some differences in the mean peak areas between the two genetic groups. A p-value of 0.100 was used for determining difference since the level of the compounds present is extremely small. The samples of the ham from the unknown Market Mix hogs had higher areas of 2-

Table 27 – Least-squares mean shear values for muscle groups used in sensory evaluation of country ham ^a

Muscle	Shear value	n
Biceps femoris	9578a	179
Semimembranosus	8820b	210
Quadriceps femoris 1	6652c	66
Quadriceps femoris 2	8641b	71
Quadriceps femoris 3	7757d	88

^a Means with like letters are not significantly different ($p>0.05$).

Table 28 – Least-squares means peak areas (in thousands of counts) averaged across processing days of volatiles isolated by solid phase micro-extraction in country hams from unknown Market Mix and Duroc pigs

Volatile	Ret. time (min)	Duroc		Market mix		p-value
		Mean ^b	Std. errors	Mean ^b	Std. errors	
Pentanal ^a	2.507	6003	1110	4646	1110	0.3958
2-Methyl butanal	2.616	2112	316	2202	326	0.8453
Acetol	2.806	403	775	1975	739	0.1589
2,2-Butanedione ^a	2.951	337	76	408	79	0.5249
3-Methylhexane	3.039	619	240	824	269	0.5760
2-Butamine	3.077	556	154	789	179	0.3367
1-Pentanol ^a	3.814	1821	431	1544	396	0.6416
Toluene ^a	4.544	1650	1314	3324	1275	0.3702
3-Methyl butanoic	5.481	158	54	283	54	0.1227
Hexane	5.609	1218	280	1074	280	0.7199
Hexanal ^a	5.735	6420	1074	4356	1074	0.1870
2-Propoxy ethanol	6.179	1332	277	744	194	0.1028
2-Methylbutanoic	6.556	322	175	1189	265	0.0296
Ethyl benzene	8.799	275	144	393	142	0.5677
3-Z-Hexenal ^a	9.063	462	182	591	187	0.6320
1,2-Dimethyl benzene	9.361	1053	341	1132	334	0.8698
p-Xylene	11.012	302	159	366	93	0.7340
2-Heptanone ^a	11.371	523	180	1090	166	0.0305
Heptanal ^a	11.860	1238	167	1003	154	0.3124
3-Methylthiopropional	12.191	1094	235	1300	223	0.5295
Benzaldehyde ^a	14.601	425	126	674	127	0.1771
1-Octen-3-ol ^a	15.475	384	75	399	71	0.8926
A trimethylbenzene	15.718	1389	548	2290	633	0.2948
Pentanoic acid ^a	15.896	586	314	974	303	0.3846
Decane ^a	16.039	153	277	834	263	0.0874
Octanal ^a	16.422	649	180	895	209	0.3829
A trimethylbenzene	16.633	457	208	852	170	0.1657
Limonene	16.968	107	85	313	76	0.1143
2-Propenylbenzene	17.038	247	117	465	126	0.2204
2-Methyldecane	17.070	166	95	326	76	0.2195
Phenylacetaldehyde ^a	17.499	2489	422	2352	399	0.8161
2,4-Dimethyldecane	18.026	138	76	266	55	0.1926
2,2,3-Trimethyl-3,4-hexanedione	18.185	167	71	278	55	0.2456
2,5-Dimethydecane	18.565	221	95	271	84	0.7025
4-Methoxyphenol	18.748	327	257	804	229	0.1814
2-Nonanone ^a	18.889	163	260	672	251	0.1732
Undecane ^a	18.999	153	222	843	210	0.340
Nonanal ^a	19.177	2461	417	2642	395	0.7562
1-Nitrohexane	20.241	173	40	177	45	0.9433
2-Methylnonane	20.612	97	30	188	32	0.0780
Heptanoic acid ^a	20.994	696	139	661	151	0.8684
Decanal ^a	21.577	200	42	189	42	0.8466
7-Methyl-4-undecene	22.833	568	139	192	186	0.1315
Octanoic acid ^a	22.884	487	167	614	174	0.6046

Table 28 (continued)

Volatile	Ret. time (min)	Market mix		Duroc		p-value
		Mean ^b	Std. errors	Mean ^b	Std. errors	
2,4-Decadienal ^a	23.705	61	37	269	34	0.0025
Dimethoxyphenol	24.625	603	244	918	261	0.3900
Nonanoic acid ^a	24.828	871	204	720	215	0.6143
Tetradecane ^a	25.551	210	112	300	106	0.5652
4-Phenyl-2-butanone	25.705	141	38	121	38	0.7198
3-Hydroxy-4-methoxy benzoic acid	26.518	205	129	171	103	0.8376
Pentadecane ^a	27.469	113	21	85	15	0.3237
An alkanoic acid	28.231	95	15	81	15	0.5067
Diethyl phthalate	28.879	192	54	222	54	0.6988
t-2-Decen-1-ol	31.454	170	48	100	46	0.3079
Tetradecanal ^a	32.340	329	80	473	76	0.7043
Di-isobutylphthalate	33.156	120	61	257	79	0.1884
Undecylamine	33.334	623	84	658	82	0.7636
Pentadecanoic acid ^a	34.333	366	64	195	66	0.0810
Dibutyl phthalate	34.472	878	340	332	340	0.2677

^a Compounds positively identified. ^b n=12.

methylbutanoic, 2-heptanone, decane, 2-methylnonane, and 2,4-decadienal. The mean peak area of pentadecanoic acid was higher in the Duroc than in the Market Mix samples. Although these differences were present, they were not large enough for a perceived difference in the perception of the ham flavor in user panels.

The compounds were also analyzed by processing day. The compounds, their retention times and a comparison of the peak areas with p-values for the 2 processing days are in Table 29. The p-value of 0.100 was once again used as an indication of significance. The hams processed on day 1 had higher mean peak areas of 2-propoxy ethanol and 3-methylthiopropional. Mean peak areas for 1-pentanol, 1,2-dimethyl benzene, p-xylene, 2-heptanone, benzaldehyde, a trimethylbenzene, phenylacetaldehyde, undecane, 7-methyl-4-undecane, octanoic acid, 2,4-decandienal, dimethoxyphenol, and tetradecane were higher in the processing day 2 hams than in the processing day 1 hams. The differences may explain the perceived differences in the intensity of the dry-cured flavor between the two processing days. These differences may be the source of differences in sensory perception of the aroma of the hams from the two processing days in the volunteer panel.

The potential aroma and taste contributions of some of the volatiles were also determined (Table 30). Many of them have aroma and tastes that would be expected in country ham, such as fatty, powerful, pungent, and rancid. Although the individual compounds make these contribution alone, when in a system the overall contribution will change as the compounds react together.

The volatiles were also grouped by class of chemical compounds. There were alcohols, aldehydes, alkanes, alkenes, amines, aromatic compounds, carboxylic acids, esters, ketones, nitro-compounds, organic acids and phenols. Table 31 shows the

Table 29 - Least -squares means peak areas (in thousands of counts) for processing days averaged across genetic groups of volatiles isolated by solid phase micro-extraction in country hams

Volatile	Ret. Time (min)	Day 1		Day 2		p-value
		Mean ^b	Std. errors	Mean ^b	Std. errors	
Pentanal ^a	2.507	6279	1187	4370	1028	0.2359
2-Methyl butanal	2.616	2462	338	1852	303	0.1917
Acetol	2.806	1987	775	389	739	0.1522
2,2-Butanedione ^a	2.951	448	82	297	73	0.1826
3-Methylhexane	3.039	657	257	786	253	0.7239
2-Butamine	3.077	502	172	844	161	0.1653
1-Pentanol ^a	3.814	635	431	2729	396	0.0019
Toluene ^a	4.544	2134	1363	2840	1222	0.7034
3-Methyl butanoic	5.481	165	54	275	54	0.1697
Octane	5.609	987	300	1304	259	0.4319
Hexanal ^a	5.735	5065	1148	5711	994	0.6743
2-Propoxy ethanol	6.179	1377	209	700	265	0.0637
2-Methylbutanoic	6.556	1006	188	505	257	0.1589
Ethyl benzene	8.799	182	179	486	93	0.1531
3-Z-Hexenal ^a	9.063	377	223	676	135	0.2773
1,2-Dimethyl benzene	9.361	396	403	1789	256	0.0096
p-Xylene	11.012	150	166	518	80	0.0643
2-Heptanone ^a	11.371	1106	186	507	159	0.0230
Heptanal ^a	11.860	1061	173	1179	148	0.6067
3-Methylthiopropional	12.191	1725	244	668	213	0.0033
Benzaldehyde ^a	14.601	295	138	804	115	0.0092
1-Octen-3-ol ^a	15.475	316	78	467	68	0.1564
A trimethylbenzene	15.718	852	671	2827	500	0.0286
Pentanoic acid ^a	15.896	593	314	968	303	0.4000
Decane ^a	16.039	287	288	700	251	0.2907
Octanal ^a	16.422	642	225	903	159	0.3551
A trimethylbenzene	16.633	non-est	non-est	655	134	0.1657
Limonene	16.968	190	76	230	85	0.7367
2-Propenylbenzene	17.038	285	142	426	96	0.4204
2-Methyldecane	17.070	193	85	299	87	0.4070
Phenylacetaldehyde ^a	17.499	1837	437	3004	382	0.0559
2,4-Dimethyldecane	18.026	150	57	255	74	0.2813
2,2,3-Trimethyl-3,4-hexanedione	18.185	144	64	301	64	0.1124
2,5-Dimethydecane	18.565	199	84	293	95	0.4779
4-Methoxyphenol	18.748	299	257	832	229	0.1368
2-Nonanone ^a	18.889	689	260	146	251	0.1475
Undecane ^a	18.999	196	236	799	195	0.0608
Nonanal ^a	19.177	2360	443	2743	366	0.5123
1-Nitrohexane	20.241	179	46	171	38	0.8899
2-Methylnonane	20.612	144	30	141	32	0.9370
Heptanoic acid ^a	20.994	677	151	680	139	0.9867
Decanal ^a	21.577	173	45	216	38	0.4760
7-Methyl-4-undecene	22.833	164	186	597	139	0.0876
Octanoic acid ^a	22.884	293	174	807	167	0.0480

Table 29 (continued)

Volatile	Ret. Time (min)	Day 1		Day 2		p-value
		Mean ^b	Std. errors	Mean ^b	Std. errors	
2,4-Decadienal ^a	23.705	92	34	238	37	0.0176
Dimethoxyphenol	24.625	442	280	1079	223	0.0907
Nonanoic acid ^a	24.828	857	222	734	196	0.6812
Tetradecane ^a	25.551	111	119	398	98	0.0756
4-Phenyl-2-butanone	25.705	143	40	120	36	0.6779
3-Hydroxy-4-methoxy benzoic acid	26.518	174	136	302	93	0.1927
Pentadecane ^a	27.469	83	19	114	19	0.2711
An alkanolic acid	28.231	92	16	84	13	0.7012
Diethyl phthalate	28.879	197	60	217	47	0.7941
t-2-Decen-1-ol	31.454	166	52	104	41	0.3716
Tetradecanal ^a	32.340	442	85	361	70	0.4699
Di-isobutylphthalate	33.156	130	84	247	54	0.2606
Undecylamine	33.334	615	89	666	76	0.6712
Pentadecanoic acid	34.333	334	73	226	57	0.2569
Dibutyl phthalate	34.472	855	377	356	298	0.3107

^a Compounds positively identified in the volatiles of the hams. ^b n=12 ham samples.

Table 30 - Aroma and taste attributable to the volatiles found in country ham samples

Volatile	Odor	Taste	Reference
1-Pentanol	fusel like	burning	Furia and Bellanca 1971
1-Octen-3-ol	powerful, sweet, earthy, strong herbaceous note	sweet, herbaceous	Furia and Bellanca 1971
t-2-Decen-1-ol	floral like orange flowers	slight fatty	Furia and Bellanca 1971
Pentanal	powerful, acrid, pungent	warm, slightly fruity, nut-like at low levels	Furia and Bellanca 1971
2-Methyl butanal	powerful, choking	sweet, slightly fruity, chocolate like	Furia and Bellanca 1971
Hexanal	Fruity	fruity	Furia and Bellanca 1971
3-Z-Hexenal	green, leafy		Furia and Bellanca 1971
Heptanal	very strong, fatty, harsh, pungent	unpleasant, fatty	Furia and Bellanca 1971
Benzaldehyde	bitter almond	bitter almond	Furia and Bellanca 1971
Ocatanal	sharp, fatty, fruity	pungent, fatty	Furia and Bellanca 1971
Phenylacetaldehyde	harsh, green, like hyacinth	unpleasant, pungent, bitter; sweet and fruity at low levels	Furia and Bellanca 1971
Nonanal	strong, fatty	fatty, citrus like	Furia and Bellanca 1971
Decanal	strong, fatty; orange rose in dilution	fatty, citrus like	Furia and Bellanca 1971
2,4-Decadienal	oily, fatty, rancid, heavy, sickening, sweaty		Dravnieks 1985
Limonene	pleasant lemon like		Furia and Bellanca 1971
Undecylamine			
Toluene	light, chemical, woody, resinous, fragrant, aromatic		Dravnieks 1985
2-Methylbutanoic	strong, green, fruity	sweet, fruity, like unripened strawberry	Furia and Bellanca 1971
Heptanoic acid	disagreeable rancid, sour sweat like, fatty		Anon 2001c
Octanoic acid	Fruity, acid	sour, fruity	Furia and Bellanca 1971
Nonanoic acid	Fatty	unpleasant	Furia and Bellanca 1971
Pentanoic acid	Powerful, acrid, pungent	warm, slightly fruity, nut-like	Furia and Bellanca 1971
2,2-Butanedione	Reverted soybean oil, rancid fat		Fisher and Scott 1997
2-Heptanone	Banana, slightly spicy		Furia and Bellanca 1971
2-Nonanone	Rue	rose, tea like	Furia and Bellanca 1971
4-Methoxyphenol	Sweet, slightly phenolic		Furia and Bellanca 1971
Dimethoxyphenol	smoky, bacon		Anon 2001c

Table 31 - Classification of volatiles found in the country ham samples

Class	Volatile
Alcohol	Acetol
	1-Pentanol
	2-Propoxy ethanol
	1-Octen-3-ol
Aldehyde	t-2-Decen-1-ol
	Pentanal
	2-Methyl butanal
	Hexanal
	3-Z-Hexenal
	Heptanal
	Benzaldehyde
	Octanal
	Phenylacetaldehyde
	Nonanal
	Decanal
	2,4 decadienal
	Tetradecanal
Alkane	3-Methylthiopropional
	3-Methylhexane
	Hexane
	Decane
	Undecane
	2-Methylnonane
	Tetradecane
	Pentadecane
	2-Methyldecane
	2,4-Dimethyldecane
	2,5-Dimethydecane
Alkene	Limonene
	7-Methyl-4-undecene
Amine	Undecylamine
	2-Butamine
Aromatic	Toluene
	Ethyl benzene
	p-Xylene
	A trimethylbenzene
	A trimethylbenzene
	2-Propenylbenzene
Carboxylic acid	1,2-Dimethyl benzene
	3-Methyl butanoic
	2-Methylbutanoic
	Heptanoic acid
	Octanoic acid
	Nonanoic acid
	Pentanoic acid
	An alkanoic acid

Table 31 (continued)

Class	Volatile
Ester	Di-isobutylphthalate Diethyl phthalate Dibutyl phthalate
Ketone	2,2-Butanedione 2-Heptanone 2-Nonanone 4-Phenyl-2-butanone 2,2,3-Trimethyl-3,4-hexanedione
Nitro compound	1-Nitrohexane
Organic acid	Pentadecanoic acid
Phenol	4-Methoxyphenol Dimethoxyphenol 3-Hydroxy-4-methoxy benzoic acid

compounds and their classifications. The aldehydes were the most numerous. Some classes of chemicals are known to contribute to the volatiles of meats.

The aldehydes present in meat are mostly from oxidation of lipids. The 2,4 decadienal has been shown to give the flavor of deep fried fat. Unsaturated aldehydes are major sources of meat and meat fat flavor. It has been suggested that they play a role in the development of species flavors. In addition to the positive flavors that aldehydes contribute to foods, they also are known to make up parts of rancid off-flavors in foods high in fat. Aldehydes are also formed in Strecker degradation reactions involving α -amino acids. One example of this is the formation of benzaldehyde from phenyl alanine in heated meats. The aldehydes are also precursors for other flavor compounds (Maarse 1991).

Ketones are found in the volatiles of meats. Many of these originate from lipids and their oxidation. Some do not make major contributions to meat flavor due to their relatively high threshold values. Others impart fatty, oily, and metallic odors to meat fat. Some ketones are also flavor enhancers in meat, especially when heated (Maarse 1991).

Another source of volatiles in meats is carboxylic acids and esters. The free fatty acids come from enzymatic hydrolysis or hydrolysis and oxidation catalyzed by heating of triglycerides and phospholipids (Maarse 1991). Long chain forms tend to increase with cooking, but are not very volatile. Therefore, they have very little impact on the aroma. Medium chained free fatty acids are more volatile and have been shown to be sources of species differentiation. Esters are formed by the esterification of alcohols and carboxylic acids. Those from shorter chained fatty acids (C1-10) impart a fruity smell to pork, while ones from longer chained fatty acids impart fatty notes. The

shorter chained ones are more common in pork as compared to other meats. Some esters have low odor thresholds, thus have been shown to contribute to the aroma of cured pork and other meats.

Other researchers have also found some of the same compounds in the volatiles of dry-cured hams. The compounds and the researchers that also found them are in Table 32. In general, most of the similarities in findings are with the more volatile compounds that had the lowest retention times. The lack of similarities in the compounds with higher retention times may be attributed to shorter gas chromatogram-mass spectrometer analysis times in some studies.

Table 32 - Compounds found in the volatiles of country ham found in this research and other studies

Volatile	Mottram and others (1984)	Ruiz and others (1999)	Hinrichsen and Pedersen (1995)	Flores and others (1997)	Ruiz and others (1998a)	Bolzoni and others (1996)
Pentanal		x	x		x	
2-Methyl butanal			x	x	x	x
Acetol						
2,2-Butanedione						
3-Methylhexane						
2-Butamine						
1-Pentanol	x				x	
Toluene	x	x		x		x
3-Methyl butanoic					x	
Hexane		x	x	x	x	
Hexanal	x	x	x	x	x	x
2-Propoxy ethanol						
2-Methylbutanoic			x		x	
Ethyl benzene	x					
3-Z-Hexenal						
1,2-Dimethyl benzene	x	x				
p-Xylene				x	x	x
2-Heptanone	x	x	x	x	x	
Heptanal				x	x	
3-Methylthiopropional	x					
Benzaldehyde	x	x			x	
1-Octen-3-ol	x		x		x	x
A trimethylbenzene		x				
Pentanoic acid						
Decane	x			x	x	
Octanal	x	x	x	x	x	x
A trimethylbenzene		x				
Limonene		x			x	
2-Propenylbenzene	x	x				
2-Methyldecane						
Phenylacetaldehyde					x	
2,4-Dimethyldecane						
2,2,3-Trimethyl-3,4- hexanedione						
2,5-Dimethydecane						
4-Methoxyphenol						
2-Nonanone	x		x		x	
Undecane	x					
Nonanal			x	x	x	
1-Nitrohexane						
2-Methylnonane						

Table 32 (continued)

Volatile	Mottram and others (1984)	Ruiz and others (1999)	Hinrichsen and Pedersen (1995)	Flores and others (1997)	Ruiz and others (1998a)	Bolzoni and others (1996)
Heptanoic acid						
Decanal	x		x	x	x	
7-Methyl-4-undecene						
Octanoic acid						
2,4-Decadienal				x	x	
Dimethoxyphenol						
Nonanoic acid						
Tetradecane						
4-Phenyl-2-butanone						
3-Hydroxy-4- methoxy benzoic acid						
Pentadecane						
An alkanoic acid						
Diethyl phthalate					x	
t-2-Decen-1-ol						
Tetradecanal						
Di-isobutylphthalate						
Undecylamine						
Pentadecanoic acid						
Dibutyl phthalate						

Chapter 5

Conclusions and Implications

This research answered many questions and developed a few new ones. Direction for sensory research was gained. Some answers were from the impact of the genetic background on sensory and some quality attributes. Some questions about other breeds and the full impact of volatiles on the evaluation of country ham have been suggested by this research.

The consumer survey gave an indication of terms that consumers associate with country ham. It also indicated which attributes they considered as positive and negative aspects of the product. Overall, most consumers think of basic terms, such as salty, meaty, and tough, in relation to country ham. Mainly individuals who could be classified as experts on the product use more advanced terms, such as nutty, barnyard and fruity. This gives a basis for terms to be used in untrained panels of sensory research on country hams.

In the present study, there were no differences in the hams from the 2 genetic groups when a panel of individuals who normally consume country ham evaluated the samples. Processors of country ham possibly do not need to use the Duroc pigs over the Market Mix for the production of country hams. The beneficial effect of genetic groups reported in sensory attributes of other pork products did not appear in country hams in this study. This suggests that there may not be benefits to producing hams from Duroc for sale as premium products over the Market Mix hams. This is positive in that pig producers can possibly get a product that is perceived to be equal to the Duroc without the extra expenses associated with raising pure breed animals. The results do leave room for other breed comparisons. Even though differences were not seen in this study,

other breeds may produce hams that have superior quality attributes that are not apparent in meat products that are not further processed. Further study with consistent production practices is warranted.

The research also shows that the genetic groups did not significantly influence the oxidation, cooking loss, and shear values of the hams. There was not enough difference in the 2 genetic groups to impact these parameters. As with the sensory results, there may be differences between other genetic groups in these quality attributes that could indicate superiority. Further research could examine these attributes in combination with sensory evaluation using different breeds for the production of the country hams.

There are differences in the volatiles content of the hams. These differences are in the quantity, not in the type, of the compounds present. The differences do not seem large enough to impact the overall perception of the product by people who normally consume it and do not cause a preference for one genetic group over another. The opportunity for further research into the volatiles of the product exists. The major contributors to the volatiles could be studied. Also, the levels of compounds required to make a difference in sensory perception could be studied.

The genetic groups did not influence most of the results of this study. However, processing day did impact the results. These differences were probably caused by the lack of control between the 2 processing days. These differences include sensory, oxidation, and volatiles differences. Many of them pertain to differences in the amount of salt that is in the final product. Future research should focus on the production itself. Currently, production of country hams is more of an art than a science. Efforts should be made to determine if it is possible to make the process more consistent.

Country ham is a product that presents of opportunity for further research. It has been traditionally a regional product, and therefore, little research has been conducted on it. The growing popularity of the product outside of the southern United States gives reason for more research on country ham. There are many aspects of the product that have yet to be thoroughly studied.

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Appendix

Country Ham Questionnaire

1. Do you consume country ham? Yes No How often?
2. Gender M F
3. Describe the appearance of the country ham slices that you normally consume.
4. What do you especially like about the appearance of such a ham?
5. What don't you like about the appearance of the ham?

Descriptor	Own words	Like	Dislike	Term
Red				
Marbled				
Bright				
Pale				
Yellow-fat				
Pink-fat				
Oily-fat				
Dry-fat				
Brown-fat				

6. Describe the aroma of the country ham that you normally consume.

7. What do you especially like about the aroma of such a ham?

8. What don't you like about the aroma of the ham?

Descriptor	Own words	Like	Dislike	Term
Fresh Meat				
Fresh Fat				
Nutty				
Mushroom				
Meaty				
Pork				
Rancid				
Strong				
Weak				
Cured				
Smoky				
Spicy				
Barnyard				
Hay-like				
Pungent				
Acorn				
Musty				

9. Describe the flavor of the country ham that you normally consume.

10. What do you like about this flavor?

11. What do you dislike about the flavor?

Descriptor	Own words	Like	Dislike	Term
Salty				
Acid				
Bitter				
Pungent				
Dry Cured Flavor				
Rancid				
Fresh Meat				
Butter				
Hazel nut				
Mushroom				
Sweet				
Off-Flavors				
Fruity				
Stale				
Tart				
Intense				
After-taste				
Musty				
Barnyard				
Hay-like				
Brown Spice				
Smoky				
Pork				
Cheesy				

12. Describe the texture of the country ham that you normally consume.

13. What do you like about the texture?

14. What do you dislike about the texture?

Descriptor	Own words	Like	Dislike	Term
Tender				
Juicy				
Chewy				
Dry				
Firm				
Fibrous				
Hard				

Judge _____ Order _____ Sample _____

You will not receive a sample with this scorecard. Please use this scorecard to rate an "ideal slice" of country ham from your knowledge and preference about the product. Place an X in the blank that best describes what you think an ideal piece of country ham should be.

Red Color

Pale _____ Dark

Overall Aroma

None _____ Intense

Pork Aroma

None _____ Intense

Rancid Aroma

None _____ Intense

Overall Flavor Intensity

None _____ Intense

Salty Taste

None _____ Intense

Sweet Taste

None _____ Intense

Pork Flavor

None _____ Intense

Rancid Flavor

None _____ Intense

Dry Cured Flavor

None _____ Intense

Texture

Extremely Dry _____ Extremely Juicy

Texture

Extremely Tough _____ Extremely Tender

Texture

Extremely Hard _____ Extremely Soft

Comments (please continue on back if more space is needed):

Please return scorecard through hatch and wait for your first sample

Judge _____ Order _____ Sample _____

You will receive two samples today. Please taste each sample and place an X on the line that best describes your opinion of the sample. Please rinse well with water between samples

Overall

Like _____ Dislike _____
Extremely _____ Extremely _____

Red Color

Pale _____ Dark _____

Overall Aroma

None _____ Intense _____

Pork Aroma

None _____ Intense _____

Rancid Aroma

None _____ Intense _____

Overall Flavor Intensity

None _____ Intense _____

Salty Taste

None _____ Intense _____

Sweet Taste

None _____ Intense _____

Pork Flavor

None _____ Intense _____

Rancid Flavor

None _____ Intense _____

Dry Cured Flavor

None _____ Intense _____

Texture

Extremely _____ Extremely _____
Dry _____ Juicy _____

Texture

Extremely _____ Extremely _____
Tough _____ Tender _____

Texture

Extremely _____ Extremely _____
Hard _____ Soft _____

Comments (please continue on back if more space is needed):

Please return your tray through the hatch and wait for your next sample

Judge _____ Order _____ Sample _____

You will receive two samples today. Please taste each sample and place an X on the line that best describes your opinion of the sample. Please rinse well with water between samples

Overall

Like _____ Dislike _____
Extremely _____ Extremely _____

Red Color

Pale _____ Dark _____

Overall Aroma

None _____ Intense _____

Pork Aroma

None _____ Intense _____

Rancid Aroma

None _____ Intense _____

Overall Flavor Intensity

None _____ Intense _____

Salty Taste

None _____ Intense _____

Sweet Taste

None _____ Intense _____

Pork Flavor

None _____ Intense _____

Rancid Flavor

None _____ Intense _____

Dry Cured Flavor

None _____ Intense _____

Texture

Extremely _____ Extremely _____
Dry _____ Juicy _____

Texture

Extremely _____ Extremely _____
Tough _____ Tender _____

Texture

Extremely _____ Extremely _____
Hard _____ Soft _____

Comments (please continue on back if more space is needed):

Please continue to the next page

Judge _____

In order to evaluate the data, we would like to have some information about you. Please provide the information below.

Your name will not be associated with the data in anyway.

Gender _____ Male
_____ Female

Age _____ younger than 20
_____ 20-29
_____ 30-39
_____ 40-49
_____ 50-59
_____ 60-69
_____ 70 and older

How often do you eat country ham?

_____ once a week or more often
_____ once every 2-3 weeks
_____ once a month
_____ once every 2-3 months
_____ once every 6 months
_____ once a year
_____ less than once a year
_____ never

Judge____ Order____ Sample____

You will receive 2 samples today. Please taste and answer the questions about each sample. Place a check on the line that best describes your opinion of the sample. Please rinse with water between samples.

Comments

Overall, how much do you like or dislike this product ?

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

How much do you like or dislike the ham aroma of the product?

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Rate the intensity of ham aroma in the product.

- ____ Much too intense
- ____ Slightly too intense
- ____ Just right
- ____ Slightly too little
- ____ Much too little

How much do you like or dislike the appearance of the product?

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Rate the color of the product.

- ____ Much too dark
- ____ Slightly too dark
- ____ Just right
- ____ Slightly too pale
- ____ Much too pale

Please continue to the next page

Judge____ Order____ Sample____

How much do you like or dislike the flavor

- ____ Like extremely of the product?
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Comments

Rate the flavor intensity in the product.

- ____ Much too intense
- ____ Slightly too intense
- ____ Just right
- ____ Slightly too little
- ____ Much too little

Rate the level of salt in the product.

- ____ Much too much salt
- ____ Slightly too much salt
- ____ Just right
- ____ Slightly too little salt
- ____ Much too little salt

Rate the level of sweetness in the product.

- ____ Much too much sweet
- ____ Slightly too much sweet
- ____ Just right
- ____ Slightly too little sweet
- ____ Much too little sweet

How much do you like or dislike the texture of the product.

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Rate the moistness/dryness of the product.

- ____ Much too juicy
- ____ Slightly too juicy
- ____ Just right
- ____ Slightly too dry
- ____ Much too dry

Rate the tenderness of the product.

- ____ Much too tender
- ____ Slightly too tender
- ____ Just right
- ____ Slightly too tough
- ____ Much too tough

Please return the tray through the hatch and wait for the next sample

Judge_____ Order_____ Sample_____

You will receive 2 samples today. Please taste and answer the questions about each sample. Place a check on the line that best describes your opinion of the sample. Please rinse with water between samples.

Comments

Overall, how much do you like or dislike this product ?

- _____ Like extremely
- _____ Like moderately
- _____ Like somewhat
- _____ Like slightly
- _____ Neither like nor dislike
- _____ Dislike slightly
- _____ Dislike somewhat
- _____ Dislike moderately
- _____ Dislike extremely

How much do you like or dislike the ham aroma of the product?

- _____ Like extremely
- _____ Like moderately
- _____ Like somewhat
- _____ Like slightly
- _____ Neither like nor dislike
- _____ Dislike slightly
- _____ Dislike somewhat
- _____ Dislike moderately
- _____ Dislike extremely

Rate the intensity of ham aroma in the product.

- _____ Much too intense
- _____ Slightly too intense
- _____ Just right
- _____ Slightly too little
- _____ Much too little

How much do you like or dislike the appearance of the product?

- _____ Like extremely
- _____ Like moderately
- _____ Like somewhat
- _____ Like slightly
- _____ Neither like nor dislike
- _____ Dislike slightly
- _____ Dislike somewhat
- _____ Dislike moderately
- _____ Dislike extremely

Rate the color of the product.

- _____ Much too dark
- _____ Slightly too dark
- _____ Just right
- _____ Slightly too pale
- _____ Much too pale

Please continue to the next page

Judge____ Order____ Sample____

How much do you like or dislike the flavor
of the product?

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Comments

Rate the flavor intensity in the product.

- ____ Much too intense
- ____ Slightly too intense
- ____ Just right
- ____ Slightly too little
- ____ Much too little

Rate the level of salt in the product.

- ____ Much too much salt
- ____ Slightly too much salt
- ____ Just right
- ____ Slightly too little salt
- ____ Much too little salt

Rate the level of sweetness in the product.

- ____ Much too much sweet
- ____ Slightly too much sweet
- ____ Just right
- ____ Slightly too little sweet
- ____ Much too little sweet

How much do you like or dislike the texture
of the product.

- ____ Like extremely
- ____ Like moderately
- ____ Like somewhat
- ____ Like slightly
- ____ Neither like nor dislike
- ____ Dislike slightly
- ____ Dislike somewhat
- ____ Dislike moderately
- ____ Dislike extremely

Rate the moistness/dryness of the
product.

- ____ Much too juicy
- ____ Slightly too juicy
- ____ Just right
- ____ Slightly too dry
- ____ Much too dry

Rate the tenderness of the product.

- ____ Much too tender
- ____ Slightly too tender
- ____ Just right
- ____ Slightly too tough
- ____ Much too tough

Please continue to the next page

Judge_____ Order_____ Sample_____

Please mark the statement that best describes your opinion of the two products

- ☐ I liked the first sample that I received better than the first
☐ I liked the second sample that I received better than the second
☐ I liked both samples equally
☐ I disliked both samples equally

Please state your reasons for liking one sample over the other:

Which of the following terms do you think best describes what type of ham this is?

- ☐ country ham
☐ smoked ham
☐ cured ham
☐ salt cured ham
☐ sugar cured ham
☐ dry cured ham
☐ wet cured ham
☐ baked ham
☐ city ham
☐ fresh ham
☐ Smithfield ham
☐ Virginia ham

Which of the following types of ham are you familiar with (mark all that apply)?

- ☐ country ham
☐ smoked ham
☐ cured ham
☐ salt cured ham
☐ sugar cured ham
☐ dry cured ham
☐ wet cured ham
☐ baked ham
☐ city ham
☐ fresh ham
☐ Smithfield ham
☐ Virginia ham

Please continue to the next page

Judge____ Order____ Sample____

In order to evaluate the data, we would like to have some information about you. Please provide the information below. Your name will not be associated with the data in anyway.

Gender ____ Male
____ Female

Age ____ younger than 20
____ 20-29
____ 30-39
____ 40-49
____ 50-59
____ 60-69
____ 70 and older

How often do you eat ham?

____ once a week or more often
____ once every 2-3 weeks
____ once a week
____ once every 2-3 months
____ once every 6 months
____ once a year
____ less than once a year
____ never

How often do you eat the type of ham you tasted today?

____ once a week or more often
____ once every 2-3 weeks
____ once a week
____ once every 2-3 months
____ once every 6 months
____ once a year
____ less than once a year
____ never

**Thank you for tasting today
Treats are in the hall**

Test of Fixed Effects

Sensory Evaluation-User Panel					
Attribute	Source of Variation	df	Mean square	F-value	Pr>F
Overall	Breed	1	8.0800	1.23	0.2688
	Processing Day	1	0.3828	0.06	0.8095
	Breed * Day	1	5.0556	0.77	0.3815
	Judge	71	11.8686	1.81	0.0007
Red color	Breed	1	10.2069	1.91	0.1690
	Processing Day	1	0.2254	0.04	0.8377
	Breed * Day	1	0.0670	0.01	0.9111
	Judge	71	15.7547	2.94	<.0001
Aroma	Breed	1	0.0847	0.01	0.9029
	Processing Day	1	0.0000	0.00	1.000
	Breed * Day	1	0.4204	0.07	0.7858
	Judge	71	12.6354	2.23	<.0001
Pork aroma	Breed	1	0.1779	0.03	0.8539
	Processing Day	1	5.3556	1.02	0.3130
	Breed * Day	1	1.269	0.24	0.6231
	Judge	71	22.7547	4.35	<.0001
Rancid aroma	Breed	1	0.0304	0.01	0.9376
	Processing Day	1	4.8204	0.97	0.3253
	Breed * Day	1	0.1703	0.03	0.8531
	Judge	71	34.1969	6.90	<.0001
Overall flavor intensity	Breed	1	0.0754	0.02	0.8941
	Processing Day	1	8.1896	1.93	0.1663
	Breed * Day	1	1.3177	0.31	0.5780
	Judge	71	14.2320	3.35	<.0001
Salty taste	Breed	1	0.0624	0.01	0.9189
	Processing Day	1	28.5211	4.75	0.0304
	Breed * Day	1	3.5869	0.60	0.4403
	Judge	71	20.9467	3.49	<.0001
Sweet taste	Breed	1	0.7656	0.19	0.6651
	Processing Day	1	2.3802	0.58	0.4454
	Breed * Day	1	2.9195	0.72	0.3982
	Judge	71	19.6955	4.84	<.0001
Pork taste	Breed	1	10.9327	2.51	0.1147
	Processing Day	1	8.1127	1.86	0.1739
	Breed * Day	1	0.4712	0.11	0.7426
	Judge	71	24.7312	5.68	<.001
Dry cured flavor	Breed	1	1.0114	0.23	0.6329
	Processing Day	1	11.0423	2.50	0.1154
	Breed * Day	1	0.0044	0.00	0.9749
	Judge	71	22.2270	5.03	<.0001

User Panel (Continued)

Attribute	Source of Variation	df	Mean square	F-value	Pr>F
Rancid flavor	Breed	1	11.9545	2.33	0.1286
	Processing Day	1	0.4051	0.08	0.7791
	Breed * Day	1	1.4401	0.28	0.5970
	Judge	71	36.9649	7.20	<.0001
Dry Texture	Breed	1	0.8749	0.16	0.6912
	Processing Day	1	21.9754	3.97	0.0475
	Breed * Day	1	2.3435	0.42	0.5158
	Judge	71	10.3187	1.87	0.0003
Hardness	Breed	1	1.9605	0.51	0.4770
	Processing Day	1	3.1690	0.82	0.3661
	Breed * Day	1	33.0094	8.55	0.0038
	Judge	71	9.6814	2.51	<.0001
Toughness	Breed	1	3.1084	0.56	0.4571
	Processing Day	1	1.0379	0.19	0.6672
	Breed * Day	1	85.7693	15.32	0.0001
	Judge	71	13.2556	2.37	<.0001

Sensory Evaluation User Panel- Deviation from Ideal

Attribute	Source of Variation	df	Mean square	F-value	Pr>F
Red color	Breed	1	10.269	1.67	0.1975
	Processing Day	1	0.3521	0.06	0.8105
	Breed * Day	1	0.0670	0.01	0.9167
	Judge	71	19.924	3.26	>.0001
Aroma	Breed	1	0.0847	0.01	0.9112
	Processing Day	1	16.2817	2.40	0.1232
	Breed * Day	1	0.4204	0.06	0.8038
	Judge	71	13.2621	1.95	0.0001
Pork aroma	Breed	1	0.1779	0.03	0.8673
	Processing Day	1	4.8204	0.76	0.3849
	Breed * Day	1	1.2688	0.20	0.6555
	Judge	71	22.8382	3.59	<.0001
Rancid aroma	Breed	1	0.0305	0.01	0.9386
	Processing Day	1	4.3134	0.84	0.3596
	Breed * Day	1	0.1703	0.03	0.8554
	Judge	71	14.3922	2.81	<.0001
Overall flavor intensity	Breed	1	0.0754	0.02	0.9017
	Processing Day	1	0.3554	0.07	0.7884
	Breed * Day	1	1.3177	0.27	0.6055
	Judge	71	14.6481	2.97	<.0001

User Panel Deviation from Ideal (Continued)

Attribute	Source of Variation	Df	Mean square	F-value	Pr>F
Salty taste	Breed	1	0.0624	0.01	0.9222
	Processing Day	1	1.4085	0.22	0.6428
	Breed * Day	1	3.5869	0.55	0.4594
	Judge	71	28.4619	2.83	<.0001
Sweet taste	Breed	1	0.7656	0.12	0.7250
	Processing Day	1	4.5634	0.74	0.3908
	Breed * Day	1	2.9195	0.47	0.4923
	Judge	71	18.4251	2.99	<.0001
Pork taste	Breed	1	10.9327	1.92	0.1669
	Processing Day	1	1.7042	0.30	0.5845
	Breed * Day	1	0.4712	0.08	0.7736
	Judge	71	12.7478	2.24	<.0001
Dry cured flavor	Breed	1	1.0114	0.18	0.6683
	Processing Day	1	101.7606	18.53	<.0001
	Breed * Day	1	0.0044	0.00	0.9775
	Judge	71	17.2161	3.13	<.0001
Rancid flavor	Breed	1	12.2612	2.04	0.1542
	Processing Day	1	2.6510	0.44	0.5069
	Breed * Day	1	1.5478	0.26	0.6120
	Judge	71	14.7472	2.46	<.0001
Dry Texture	Breed	1	0.8749	0.12	0.7260
	Processing Day	1	105.3833	14.84	0.0002
	Breed * Day	1	2.3435	0.33	0.5663
	Judge	71	27.7539	3.91	<.0001
Hardness	Breed	1	1.9605	0.44	0.5071
	Processing Day	1	19.2817	4.34	0.0384
	Breed * Day	1	33.0094	7.43	0.0069
	Judge	71	21.2102	4.78	<.0001
Toughness	Breed	1	3.3649	0.49	0.4857
	Processing Day	1	8.0774	1.17	0.2805
	Breed * Day	1	87.0947	12.62	0.0005
	Judge	71	26.5922	3.85	<.0001

Volunteer Sensory Panel

Attribute	Source of Variation	df	Mean square	F-value	Pr>F
Overall	Processing Day	1	57.3298	27.69	<.0001
	Breed	1	10.8213	5.23	0.0260
	Breed * Day	1	2.0078	0.97	0.3289
	Judge (day)	58	5.6204	2.71	0.0001
Flavor	Processing Day	1	56.5761	23.76	<.0001
	Breed	1	8.8653	3.72	0.0587
	Breed * Day	1	3.5772	1.50	0.2254
	Judge (day)	58	4.7772	2.01	0.0047
Aroma	Processing Day	1	21.6750	10.19	0.0023
	Breed	1	6.0750	2.85	0.9650
	Breed * Day	1	3.0083	1.41	0.2393
	Judge (day)	58	3.3037	1.55	0.0483
Appearance	Processing Day	1	39.6750	17.66	<.0001
	Breed	1	0.2083	0.09	0.7618
	Breed * Day	1	0.0083	0.00	0.9515
	Judge (day)	58	4.6060	2.05	0.0035
Texture	Processing Day	1	53.3333	24.41	<.0001
	Breed	1	7.5000	3.43	0.0690
	Breed * Day	1	10.8000	4.94	0.0301
	Judge (day)	58	5.2075	2.38	0.0006

Physical and Chemical Tests

Test	Source of Variation	df	Mean square	F-value	Pr>F
Oxidation	Breed	1	0.1635	1.86	0.1802
	Processing Day	1	2.2690	25.84	<.0001
	Panel	5	0.1598	1.82	0.1315
	Breed * Day	1	0.10009	1.15	0.2902
Cooking Loss	Breed	1	6.3000	0.00	0.9695
	Processing Day	1	10.9349	0.00	0.9598
	Breed * Day	1	32.4587	0.01	0.9309
Shear Value	Breed	1	730495.0	0.14	0.7097
	Processing Day	1	114168578.0	21.67	<.0001
	Breed * Day	1	10233312.0	1.94	0.1639
	Muscle	4	116951151.6	22.20	<.0001

VITA

Susan Gail Key was born in Knoxville, Tennessee to Claude and Rita Key. She graduated high school from Webb School of Knoxville. She then went to the University of Tennessee, Knoxville majoring in Food Science and Technology with a minor in General Business. She was a Tennessee Scholar. She was an intern for Purity Dairies and Fresh Express Foods. She obtained her Bachelor's Degree in May 1999 graduating Summa Cum Laude. She continued at the University of Tennessee, Knoxville pursuing a Master's degree in the Fall of 1999. She served as a Graduate Teaching Assistant for introductory agriculture class and as a Graduate Research Assistant in the sensory evaluation laboratory. She is a member of Phi Eta Sigma Honor Society, Gamma Beta Phi Honor Society, Phi Kappa Phi Honor Society, Alpha Zeta Agricultural Honor Society, Gamma Sigma Delta Honor Society, and Omicron Delta Kappa Honor and Leadership Society. Susan is also a member of the Institute of Food Technologists.