Contribution of lean, fat, muscle color and degree of doneness to pork and beef species flavor

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1. Introduction

Consumers primarily base their evaluations of cooked meat on three categories: tenderness, juiciness, and flavor (Spanier & Miller, 1993). Of these attributes, flavor is often rated as the most important but is also the least understood. Meat flavor is created by compounds that are derived from either lean or fat tissues and can be divided into two categories – the characteristic meat flavor common to all species of animals and the specific flavor of beef, pork, lamb or other species. In order to provide consumers with meat products that have desirable flavor, one must understand how to influence, promote, and preserve meat flavor in both fresh and processed products.

Meaty flavor, shared by all species, is traditionally associated with the lean tissue. According to Mottram (1998a) sugars, amino acids, organic and inorganic salts are responsible for the sweet, sour, salty, and bitter flavors typical of meat. It is believed that the Maillard reaction coupled with lipid oxidation are the two processes most important to forming the characteristic flavor of cooked meat (Warriss, 2000). Higher temperatures lead to more Maillard reaction products (Imafidon & Spanier, 1994). Therefore, meaty flavor intensity may be impacted by degree of doneness, lean to fat ratios in the product, degree of lipid oxidation and other factors.

Species-specific flavors, however, have been traditionally associated with the fat tissue. Hydrocarbons, alcohols, ketones, and aldehydes from lipid oxidation influence species-specific flavor (Imafidon & Spanier, 1994; Mottram, 1998b). Furthermore, fat-soluble volatile aromatic compounds and phospholipids (Melton, 1999) may also contribute to species-specific flavor. Therefore, both the species of origin and the amount of fat in a product may contribute to the overall species-specific flavor of meat. Mottram (1977) conducted triangle tests using beef and pork lean and found that the inclusion of 10% fat, regardless of species origin, enabled taste panelists to distinguish lean type when compared to samples with no added fat. Berry (1994) did not concur, but found that when comparing beef patties with 4% and 20% fat, the higher fat samples had greater beef flavor scores. Cross, Berry, and Wells (1980) examined differences in several sensory aspects of ground, all-beef patties with different fat levels of 16%, 20%, 24%, and 28%; no differences were found in ground beef flavor intensity.

Furthermore, various muscles have different flavor profiles based on color, location, and function in the body (Xiong, Ho, & Shahidi, 1999). Previous work has indicated there are more phospholipids in red, oxidative muscles than white, glycolytic muscles (Beecher, Cassens, Hoekstra, & Briskey, 1965; Lefaucheur & Gerrard, 1998) suggesting they may have more intense flavor. Higher iron concentrations and energy stores present in darker muscles may also contribute to flavor intensity (Xiong et al., 1999; Young & West, 2001). Therefore, it is believed dark muscles have more intense flavor than light muscles.

This study had multiple objectives that were addressed by three different experiments. The first objective (Exp. 1) was to determine the influence of species-specific lean and fat source, as well as the interaction of species specificity with degree of doneness on species-specific meat flavor. The second objective (Exp. 2) was to determine how meat flavor was affected by varying fat levels.
The third objective (Exp. 3) was to determine if there were differences in flavor between dark and light muscles in ground product.

2. Materials and methods

2.1. Species specificity and degree of doneness (Exp. 1)

The meat for all three studies was obtained from the University of Illinois Meat Science Laboratory. For this experiment, three separate batches each of beef lean (chuck and round), pork lean (shoulder and leg), beef fat, and pork fat were collected. Lean tissue was trimmed of all visible fat. Fat tissue was trimmed of all visible lean. Batches were ground through a 1.27 cm plate, mixed by hand, and then ground again. Sub-samples of each batch were analyzed for fat content using the proximate analysis (PA) procedures of Novakofski, Park, Bechtel, and McKeith (1989) and each batch was vacuum-packaged and stored at 4 °C.

The results of the PA of each batch was used to formulate 80:20 lean to fat ratios for each of the four composites: beef/lean/beef fat (BL/BE), beef/lean/pork fat (BL/PF), pork/lean/pork fat (PL/PF), and pork/lean/beef fat (PL/BE). This resulted in 3 independent replications of each formulation. The meat and fat components for each of these formulations were weighed out, mixed by hand, then ground twice using a 0.95 cm plate with mixing between the two grinds. The grinder was cleaned between each batch.

Patties (113.4 g each) were formed with hand patty presses, laid out in single layers on trays, covered with wax paper and placed at −20 °C for 12 h. Once frozen, the patties were vacuum packaged without damaging their shape and placed back into the freezer.

2.2. Fat concentration (Exp. 2)

Three separate batches each of beef lean (chuck and round), pork lean (shoulder and leg), beef fat, and pork fat were collected. Lean tissue was trimmed of all visible fat. Fat tissue was trimmed of all visible lean. Batches were ground through a 1.27 cm plate, mixed by hand, and then ground again. Sub-samples were taken for PA, and then batches were vacuum-packaged and stored at 4 °C.

From the PA, eight single species formulations were made: beef with 5% fat (B5), beef with 10% fat (B10), beef with 15% fat (B15), beef with 20% fat (B20), pork with 5% fat (P5), pork with 10% fat (P10), pork with 15% fat (P15), and pork with 20% fat (P20). The three batches of meat collected above resulted in 3 replications of each formulation. The meat and fat components for each of these formulations were weighed out, mixed by hand, and then ground twice using a 0.95 cm plate with mixing between the two grinds. The grinder was cleaned between batches of beef and pork. Patties were made from each formulation using patty presses, frozen overnight, packaged, and placed at −20 °C for storage as described above.

2.3. Muscle color (Exp. 3)

Muscle groups were chosen based on light and dark color. Shank, Psoas major, Supraspinatus, and Serratus ventralis were chosen as the dark muscles in both beef and pork, while the Semimembranosus and Semitendinosus were chosen as light muscles (Jones, Guru, Singh, & Jones, 2006; Kirchofer, Calkins, & Gwartney, 2002). Three separate batches of each light pork, dark pork, light beef, and dark beef lean were trimmed of excess fat, ground through a 0.95 cm plate twice, mixing between the two grinds. Each batch of lean was allowed to bloom for 15 min and objective color measurements were taken with a Minolta Chromometer CR-300 (Minolta Camera Co. Japan, Illuminant D65 and 0° observer) to verify differences in lean color. Six batches of each beef fat and pork fat were trimmed of lean, and ground using the same procedure. Samples were taken for PA, and then batches were vacuum-packaged and stored at 4 °C.

From the PA, 80:20 lean to fat formulations were made of dark beef and beef fat (BD), light beef and beef fat (BL), dark pork and pork fat (PD), and light pork and pork fat (PL). Lean and fat were weighed for each formulation, mixed by hand, ground through a 0.95 cm plate twice, mixing between grinds. The grinder was cleaned between batches of beef and pork. Patties were made from each formulation and held at −20 °C for storage.

2.4. Sensory analysis

Sensory analysis was conducted in accordance with American Meat Science Association research guidelines for cookery and sensory evaluation (1995). Patties were thawed at 4 °C overnight, and cooked on Farberware open hearth grills (Walter Kiddle, model 455N, Bronx, NY) to an internal temperature of 71 °C for Exp. 2 (fat concentration) and Exp. 3 (muscle color). For Exp. 1, half of the patties were cooked to 66 °C (low) and half were cooked to 71 °C (regular). All patties were flipped when internal temperature reached half of the desired final cooking temperature. Internal temperature was monitored using copper-constantan thermocouples (Type T, Omega Engineering, Stanford, CT) connected to a digital scanning thermometer (Model 92000-00 Barnant Co., Barington, IL). After cooking, each patty was cut into eight equal wedges and placed in a foil pouch. The foil pouch was passed to the panelists to smell the samples and then take a piece for tasting. A six-member trained sensory panel measured sensory attributes of all patties. For each experiment, two panels were served per day for three days. Panelists were asked to score samples for beef flavor, pork flavor, metallic/serumy, or acidic/sour flavors. A 15 cm anchored line scale was used to measure flavor attributes with 0 being no beef, pork, metallic/serumy, or acidic/sour flavors and 15 being intense flavors.

2.5. Proximate analysis

Fat contents of raw and cooked patties were determined according to the procedures of Novakofski et al. (1989). This allowed us to confirm formulations were correct and to use fat content as a covariate in analyses where appropriate.

2.6. Statistical analysis

Statistical analysis was performed using SAS (SAS Institute, Cary, NC). For Exp. 1, the general linear models (GLM) procedure was used with a model including the effects of species lean, species fat, their interaction and final cooking temperature. Fat level of raw patties was used as a covariate. To determine the relative importance of lean and fat species, partial R² were calculated by dividing the Type II sums of squares for either lean or fat by the total sums of squares. For Exp. 2, sensory results were regressed against the fat level in the raw product. In Exp. 3, GLM was used with a model including the effects of species, muscle type and their interaction. Means and standard error were calculated by the LSMEANS procedure and means were separated using the PDIFF (probability of difference) option. Differences were detected at the P < 0.05 level unless otherwise noted.

3. Results and discussion

3.1. Species specificity (Exp. 1.)

The objective of the first study was two-fold: first, to determine the influence of species-specific lean and fat sources on the overall...
Beef flavor

<table>
<thead>
<tr>
<th></th>
<th>Beef fat</th>
<th>Pork fat</th>
<th>Pork lean</th>
<th>Beef fat</th>
<th>Pork fat</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef flavor</td>
<td>6.03a</td>
<td>5.32a</td>
<td>1.34b</td>
<td>0.68b</td>
<td>0.31b</td>
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<tr>
<td>Metallic/serumy flavor</td>
<td>1.30b</td>
<td>1.50b</td>
<td>0.20a</td>
<td>0.25a</td>
<td>0.15a</td>
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<tr>
<td>Pork flavor</td>
<td>0.41a</td>
<td>1.04a</td>
<td>4.16b</td>
<td>5.14c</td>
<td>0.24c</td>
<td></td>
</tr>
<tr>
<td>Acidic/sour flavor</td>
<td>0.25a</td>
<td>0.42a</td>
<td>0.39b</td>
<td>0.81b</td>
<td>0.13b</td>
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</tr>
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</table>

Within the row, means with different superscripts differ (P < 0.05).

1 Flavor measured on a scale from 0 (no flavor) to 15 (strong flavor).

2 All formulations consisted of 80% lean + 20% fat patties cooked to 71 °C.

Table 1
Beef and pork flavor in samples with mixed species contributions.

Flavor profile, and secondly, to determine the interaction of species specificity with degree of doneness. Degree of doneness did not have a significant effect on any flavor component analyzed (P > 0.05) nor did it interact with species of lean or fat source. Previous studies (Berry, 1994; Kregel, Prusa, & Hughes, 1986) demonstrated flavor differences were distinguishable when cooking patties to 71 °C and 77 °C. Our experiment, performed at lower temperatures, did not concur. It is possible that these lower temperatures did not allow for adequate Maillard reaction product formation to differentiate flavor intensity between the two temperatures. Because the degree of doneness did not impact the intensity of pork or beef flavor in these samples, the values from the two temperatures were pooled for the analysis of species-specific flavors.

For all-beef, pork and acidic/sour flavors, the effects species lean and species fat source were both significant (P < 0.05). For metallic flavor, only the species lean source was significant. There were no interactions of species lean and fat sources (P > 0.25), thus flavors from fat and lean were completely additive. However, means for the interaction of species lean and species fat source are presented in Table 1. Beef flavor was higher (P < 0.05) in samples prepared with beef lean compared to those with pork lean. However, the addition of beef fat, as opposed to pork fat, to beef lean, however, did not further increase beef flavor. Results for metallic flavor were similar to those for beef flavor with beef lean samples having higher (P < 0.05) metallic flavor intensity than pork lean samples but no additional intensity was achieved with the addition of beef fat. Pork flavor was higher (P < 0.05) in samples prepared with pork lean as opposed to beef lean. The addition of pork fat increased (P < 0.05) the pork flavor of samples made with pork lean but not samples made with beef lean. Acidic/sour flavor was higher (P < 0.05) in pork lean/pork fat samples than any other samples prepared including pork lean/beef fat samples.

Table 2
Variability explained by lean and fat source in mixed samples.

<table>
<thead>
<tr>
<th></th>
<th>Lean</th>
<th>Fat</th>
<th>Lean and fat</th>
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</thead>
<tbody>
<tr>
<td>Beef flavor</td>
<td>0.90</td>
<td>0.02</td>
<td>0.92</td>
</tr>
<tr>
<td>Metallic flavor</td>
<td>0.74</td>
<td>0.06</td>
<td>0.75</td>
</tr>
<tr>
<td>Pork flavor</td>
<td>0.90</td>
<td>0.03</td>
<td>0.93</td>
</tr>
<tr>
<td>Acidic/sour flavor</td>
<td>0.21</td>
<td>0.09</td>
<td>0.40</td>
</tr>
</tbody>
</table>

*R² = Model sums of squares/total sums of squares.

Overall, the results from Exp. 1 contradict the commonly held opinion that lean tissue has a general meaty flavor, while fat generates species-specific flavors. The acidic/sour flavor, more characteristic of pork than beef, however, was strongly influenced by fat species. The other flavors evaluated in this experiment (beef flavor, pork flavor, metallic/serumy), however, indicate that species lean source is the major determinant of species-specific flavor in samples with 20% fat. While contradictory to the long-held belief that “fat equals flavor”, these results do have some previous support. Mottram, Edwards, and Macfie (1982) also found that beef lean has species-specific flavor. Wasserman and Spinelli (1972) suggested that the inherent biochemical components of fat and lean tissues work in tandem to develop flavor. More research, perhaps using consumers instead of trained panelists, may be useful in determining the tissue origin of species-specific flavor.

3.2. Fat concentration (Exp. 2)

In the fat concentration experiment (Exp. 2), our goal was to determine how meat flavor was affected by increasing fat levels. Unlike Exp. 1, samples were prepared with beef lean and fat or pork lean and fat. No mixed species samples were used. Samples were formulated with increasing levels of fat from 5% to 20%. Results of regression analyses of beef and metallic/serumy flavor in beef samples, and pork and acidic/sour flavor in pork samples are presented in Fig. 1.

In the pork samples, there was an increase in pork flavor intensity as pork fat concentration increased (P < 0.05) (Fig. 1). The high correlation coefficient (R² = 0.79) indicated that a large degree of the variation in pork flavor between samples could be attributed to differences in fat level. There are mixed results in the literature regarding increased fat content in pork and pork flavor. However, most of the previous research investigated the correlation of intramuscular fat levels to flavor intensity. An earlier study found that taste panelist scores showed that intramuscular fat level had no correlation to flavor intensity (Blanchard, Willis, Warkup, & Ellis, 2000). Furthermore, Rincker, Killefer, Ellis, Brewer, and McKeith (2008), found that consumer panelists did not give higher pork flavor scores to chops that had more extricable lipid ranging from 1% to 8%. Our experiment did not rely on intramuscular fat for flavor, but instead attempted to drive flavor intensity by the addition of subcutaneous fat and reflected the findings of previous work that suggested increased subcutaneous fat levels increased flavor intensity in ground pork product. Mottram et al. (1982) added 10% subcutaneous pork fat to pork lean and found that pork flavor increased. Acidic or sour flavor, which was associated with pork lean in Exp. 1, however, was not impacted by the addition of pork fat. We considered acidic/sour flavor to be a second descriptor of pork flavor and therefore, it is unclear why it was not changed by varying levels of fat. It is possible that panelists perceived a constant level of acidity or sourness associated with pork lean and that was unchanged by the addition of pork fat.

In contrast to pork flavor, beef flavor intensity in beef samples did not change (P > 0.05) with the addition of fat (Fig. 1). There are conflicting data regarding the effect of fat level on beef flavor. It has been generally accepted that an increase in fat content, particularly through higher marbling scores, increases beef flavor (Aberle, Forrest, Gerrard, & Mills, 2001). Our study agreed with
data from Cross et al. (1980) that determined beef flavor does not increase as fat is added. Mottram et al. (1982) found that adding fat did not increase lipid-derived volatiles in beef and pork patties and therefore concluded that the intramuscular fat or structural lipids in muscle could be the most important sources for volatiles. Metallic/serumy flavor, however, decreased as beef fat level increased \((P < 0.05)\) (Fig. 1). The dilution effect on metallic/serumy flavor caused by increased fat level suggests that metallic/serumy flavor was more associated with the lean component, which concurs with results of Exp. 1. Furthermore, the correlation coefficient \(R^2 = 0.47\) revealed that differences in fat content accounted for less than half of the variability in metallic/serumy flavor indicating that other factors are important in determining this flavor in beef samples.

### 3.3. Muscle color

The objective of the muscle color experiment (Exp. 3) was to determine if there was a difference in flavor between dark and light muscles when used in ground product. Similar to Exp. 2, beef lean (light and dark) was mixed only with beef fat, and pork lean (light and dark) with pork fat. No mixed species samples were used. Consistent with the results from Exp. 1, beef flavor and metallic/serumy flavor was higher in beef samples than in pork, while pork flavor and acidic/sour flavor tended to be greater in pork samples (Table 3). Beef flavor, metallic flavor, and pork flavor were not impacted by muscle color. Acidic/sour flavor, however, was increased in light muscles compared with dark muscles. It is possible that the acidic/sour flavor is correlated to pH with lighter muscles tending to have a lower pH and more acidic/sour flavor. It has, however, been previously reported that darker whole muscles have more flavor than lighter muscles, perhaps due to increased fat or nucleotide levels (Xiong et al., 1999). Our results do not concur with this previous finding. However, compared to the samples of Xiong and co-workers, our samples were higher in fat and held at a constant fat level, which may negate the difference in flavors between muscle groups.

### 4. Conclusions

Historically, species-specific flavor has been attributed to the fat in meat products. However, our results indicate that the lean tissue in meat products may be the principle contributor to species-specific flavors. In mixed species samples, the predominant flavor was determined by the lean species. Furthermore, increasing fat content in beef samples did not increase beef flavor, and in fact, decreased metallic/serumy flavor that was previously shown to be associated with beef samples. Fat in certain meat products, however, still plays a role in species-specific flavors as increasing fat levels in pork samples led to increased flavor. The acidic/sour flavor previously shown to be associated with pork, however, was not impacted by fat content. Acid/sour flavors were shown to be associated with light muscles of both beef and pork suggesting it may be related to pH or fiber type of the muscle. Overall, this research suggests that increased fat content in meat products may not always relate to increased flavor and that the lean component of meat may be the main source of species-specific flavor.

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**Table 3** Beef and pork flavor in samples with light and dark muscles.

<table>
<thead>
<tr>
<th></th>
<th>Beef</th>
<th>Pork</th>
<th>Light</th>
<th>Dark</th>
<th>Light</th>
<th>Dark</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beef flavor</td>
<td>6.41\textsuperscript{a}</td>
<td>5.79\textsuperscript{a}</td>
<td>0.52\textsuperscript{b}</td>
<td>0.42\textsuperscript{b}</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metallic/serumy flavor</td>
<td>1.98\textsuperscript{a}</td>
<td>1.65\textsuperscript{b}</td>
<td>0.18\textsuperscript{b}</td>
<td>0.13\textsuperscript{b}</td>
<td>0.17</td>
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</tr>
<tr>
<td>Pork flavor</td>
<td>1.00\textsuperscript{a}</td>
<td>0.82\textsuperscript{b}</td>
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<td>5.62\textsuperscript{a}</td>
<td>0.38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acidic/sour flavor</td>
<td>0.09\textsuperscript{a}</td>
<td>0.45\textsuperscript{c}</td>
<td>0.71\textsuperscript{b}</td>
<td>1.20\textsuperscript{b}</td>
<td>0.14</td>
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</tr>
</tbody>
</table>

\textsuperscript{a,b,c}Within a row, means with different superscripts differ \((P < 0.05)\).

\textsuperscript{1}Flavor measured on a scale from 0 (no flavor) to 15 (strong flavor).
References


