Descriptive flavor analysis of bacon and pork loin from lean-genotype gilts fed conjugated linoleic acid and supplemental fat[1]

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ABSTRACT: This study evaluated the combined effects of dietary CLA and supplemental fat (SF) source on organoleptic characteristics of bacon and pork loin samples in lean-genotype gilts (n = 144). Gilts (49.3 kg of BW) were randomly assigned to a 3 × 2 factorial design, consisting of SF [0% SF, 4% yellow grease (YG), or 4% tallow] and linoleic acid (LA; 1% corn oil or 1% CLA). Animals were slaughtered (113 kg) after a feeding period of 47 d. A trained sensory panel (n = 6 members) developed a flavor profile on commercially cured bacon samples (12 descriptors) and center-cut, boneless, pork loin chops (18 descriptors, using a 14-point, universal intensity scale). Bacon samples from pigs fed 4% SF were considered to have a sweeter flavor (4.07 ± 0.07) than those fed 0% SF (3.89 ± 0.07; $P < 0.04$). The intensity of salty flavor was greater in bacon samples from pigs fed LA (6.18 ± 0.09) compared with those fed CLA (5.86 ± 0.10; $P < 0.04$). The intensity of salty aftertaste of bacon was greater when LA was combined with YG (5.21 ± 0.14; $P < 0.07$) or tallow (5.44 ± 0.14; $P < 0.01$) than for LA alone (4.85 ± 0.14, but SF combined with CLA was not different from CLA alone (fat × LA; $P < 0.02$). Sour flavor intensity tended to be lower in loin samples from pigs fed CLA than for those fed LA (1.60 vs. 1.73 ± 0.06; $P < 0.09$). Samples from animals fed 4% tallow tended to have lower ($P < 0.09$) notes of astringent aftertaste (1.42 ± 0.08) compared with those fed 0% SF (1.62 ± 0.09) or 4% YG (1.66 ± 0.09). Overall, the flavor differences for bacon and loin samples were minimal, with most means differing by 1 point or less on the 14-point intensity scale. The sensory panel results indicate consumer acceptance of bacon and pork products from pigs fed CLA will not likely differ from commodity pork products.

Key words: pork quality, conjugated linoleic acid, sensory analysis, supplemental fat, taste panel

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INTRODUCTION

Consumption of bacon is on the rise, and from May 2002–May 2003 retail refrigerated bacon sales were just over $2 billion, equating to 4.2% increase compared with the previous year (Bardic, 2003). Accordingly, the quality of pork bellies composed of soft fat depots is an increasing concern for packers and processors (Morgan et al., 1994). Uniformity and composition of pork fat are quality concerns because thin bellies and soft fat produce more miss-cuts and a greater percentage of lower quality product (Morgan et al., 1994). One possible solution to the soft belly fat problem is to supplement diets with a highly saturated fat source.

We have shown that increasing saturation of supplemental fat increased pork belly thickness (Averette Gatlin et al., 2003). However, consumer preferences and American Heart Association (2001) recommendations suggest consumption of a diet containing increased unsaturated to saturated fat ratios, with up to 10% of energy as PUFA. In this regard, supplementation of swine diets with CLA, a PUFA, has also been shown to increase saturated fat content and thus belly firmness (Eggert et al., 2001; Thiel-Cooper et al., 2001). Data from our previous study showed that the CLA enrichment of pork could be enhanced when CLA was fed and especially when fed with additional dietary fat (Averette Gatlin et al. 2002).

Recent research examining the effects of CLA on pork quality have primarily examined the impact of CLA on loin muscle quality and palatability (Dugan et al., 1999; Weigand et al., 2001, 2002). Our previous work has shown that CLA supplementation can alter the ratio of saturated to unsaturated fatty acids in pork (Averette

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Gatlin et al. 2002). In addition, little is known about how these changes affect the consumer in regards to sensory attributes.

Therefore, our objective of this study was to determine if CLA-enriched pork or pork from pigs supplemented with a saturated fat source (tallow; iodine value = 47) and CLA combined would affect the sensory quality of loin and bacon samples compared with samples from pigs fed CLA combined with a more unsaturated fat source [yellow grease (**YG**); IV = 83].

MATERIALS AND METHODS

Live Animal Care and Measurements

All animal procedures were approved by the Institutional Animal Care and Use Committee of North Carolina State University. Details of animal procedures, diets, and carcass characteristics have been published previously (Averette Gatlin et al., 2002). In brief, lean genotype gilts (n = 144; average weight 49.3 kg) were randomly assigned to 1 of 6 treatments according to a 3 × 2 factorial design (24 pigs per treatment). Treatments included 3 sources of supplemental fat (**SF**) and 2 sources of linoleic acid (**LA**), as follows: 1) 0% SF + 1% LA; 2) 0% SF + 1% CLA; 3) 4% YG + 1% LA; 4) 4% YG + 1% CLA; 5) 4% tallow + 1% LA; 6) 4% tallow + 1% CLA. The source of CLA contained approximately 60% conjugated isomers (Natural Lipids, Sandvika, Norway). Animals received ad libitum access to their respective diet and to water for 47 d until they reached an average slaughter weight of 113 kg.

Flavor Analysis

A subset of bellies (n = 8/treatment) and LM chops (n = 8/treatment) were collected for taste panel evaluation. Bellies were processed in a commercial facility and pumped for a 20% increase in raw weight with a cure containing salt, sodium nitrite (6.25%), sodium erythorbate (2.5%), sugar, flavorings, FD & C Red #3 (0.00022%), and not more than 1% sodium carbonate. Bellies were then smoked for 24 h, sliced, vacuum-packaged, and frozen for storage until analysis. Loin chops were cut into 2.54-cm slices, vacuum-packaged, and frozen within 24 h of slicing. Samples were evaluated within 3 mo of collection. Flavor characteristics of cooked samples were determined using a professional 6-member flavor profile panel.

Panelists were screened, selected, and trained according to standards of the American Society of Testing Materials STP 750 (1981) and the methods of Caul (1957) and Cairncross and Sjostrom (1950). Panelists developed the pork loin and bacon lexicons (Tables 1 and 2) using retail or test diet samples during 5 and 3 training sessions, respectively. Boneless pork loin chops from a local grocery and Hormel Black Label bacon were used as reference standards. Aroma, flavor, and aftertaste attributes were quantified using a universal intensity scale ranging from 0 (minimum intensity) to 14 (maximum intensity; Cairncross and Sjostrom, 1950). The sampling order was designed to minimize carryover effects within each panel session (MacFie, 1989). Descriptors for flavor, aroma, and aftertaste of the bacon samples and loin chop samples are described in Tables 1 and 2, respectively.

Samples were removed from the freezer 20 to 24 h before cooking and thawed in a refrigerator. A KitchenAid grinder (Hobart Manufacturing Co., Troy, OH) with a meat attachment was used to grind the LM from the loin chop samples, and 28 g was weighed into glass jars. Samples were flattened in the jars, covered with foil, and baked at 177°C for 15 min. The internal temperature was monitored using a thermometer connected to a thermocouple (Omega Engineering Inc., Stamford, CT) placed in prewarmed jars for evaluation. Once cooked, the glass jars were placed in sand trays (preheated to 93°C) and kept on warming trays throughout the evaluation. Samples were served in random order within each panel session to each panelist.

In addition, the panelists evaluated the flavor and aftertaste of the bacon samples. Bacon samples from the center of each belly were cooked on a commercial griddle (Model XL-18, Lang Manufacturing Co., Everett, WA) for 3 min on each side. The slices were then blotted on paper towels to remove excess grease, placed in a pan on foil, and kept in the oven at 82°C until given to the panelists in random order.

Statistical Analysis

Data were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC). Least squares treatment means were obtained assuming fixed models that included the effects of slaughter group, SF, LA source, and SF × LA source interaction. The df were partitioned into contrasts for the effects of SF source (YG vs. tallow) and SF level (0 vs. 4%).

RESULTS

Animal performance, carcass quality, and fatty acid composition have been described in depth previously (Averette Gatlin et al., 2002). Taste panel ratings of bacon and loin samples are shown in Tables 3 and 4, respectively. Bacon samples from pigs fed 4% supplemental fat were considered to have a sweeter flavor than those fed 0% supplemental fat ($P < 0.04$). Salty flavor intensity was increased in samples from pigs fed LA compared with those fed CLA ($P < 0.02$). Feeding CLA increased the intensity of fat flavor in bacon from pigs fed 0% supplemental fat but not those fed 4% supplemental fat ($P < 0.09$). Lean flavor of bacon was slightly reduced with CLA supplementation ($P < 0.10$). Overall burnt flavors were low on the intensity scale, but slightly higher with CLA supplementation in bacon samples from pigs fed 0% supplemental fat or 4% YG but not in those from pigs fed 4% tallow ($P < 0.09$). The

Table 1. Definitions used by trained sensory panelists to describe the flavor and aftertaste of bacon

Descriptor	Definition
Smoked	Volatiles typical of meat cured with smoke, real or artificial
Sweet	Taste on the tongue stimulated by sugars
Salt	Taste on the tongue stimulated by sodium salt
Cured fat	Aromatic of the cooked fat portion of processed meat containing curing agents
Cured lean	Aromatic of the cooked lean portion of processed meat containing curing agents
Cured meat/fatty	A complex of both cooked lean and fat cured meat
Brown sugar	Aromatic of brown sugar, rich and sweet
Molasses	A slightly sulfury, sharp, sweet aromatic associated with molasses
Burnt	Aromatic associated with overcooked, sometimes blackened food

Table 2. Definitions used by trained sensory panelists to describe the aroma, flavor, and aftertaste of loin samples

Descriptor	Definition
Oxidized	General term for the oxidized characteristic(s) of foods such as cardboard, painty, and stale
Cooked, uncured pork	Associated with cooked lean pork muscle and fat aromatic
Warmed over flavor	Aromatic associated with uncured cooked pork after up to 48 h of refrigerated storage and reheated
Metallic	Penny held in the mouth
Briny	Aromatic of salt in solution
Boar taint/piggy	Musk-like aromatic associated with boar meat; hormone-like; uncured
Sour	Pungent, sharp aromatic; also the basic taste on the tongue associated with acids
Sweet	Basic taste stimulated on the tongue by sugars and high potency sweeteners
Astringent	Mouth feel sensation of shrinking, drawing, or puckering of skin surfaces of the oral cavity, or tooth coating or edginess, leaving a dry feeling in the mouth
Bitter	Taste stimulated by substances such as caffeine or quinine when solubilized
Salt	Salt water; also basic taste on the tongue stimulated by sodium salt
Browned	Aromatic associated with Maillard browning (AA and reducing sugars); the outside of grilled or broiled meat
Meaty	General aromatic of cooked meat, possibly nonspecific as to the type of meat

Table 3. Flavor and aftertaste, as rated by a trained sensory panel, of bacon from pigs consuming 0 or 4% supplemental fat combined with linoleic acid (LA) or CLA

	0% Supplemental fat		4% Yellow grease		4% Tallow		
Descriptor	LA	CLA	LA	CLA	LA	CLA	SEM
Flavor							
Sweet[1]	3.98	3.81	4.13	4.08	3.96	4.10	0.09
Salty[2]	5.88	5.94	6.38	5.90	6.29	5.76	0.17
Smoked	5.65	5.66	6.04	5.59	5.71	5.66	0.14
Fat[3]	5.33[a]	5.81[b]	5.77[b]	5.83[b]	5.63[b]	5.59[ab]	0.12
Lean[4]	5.06	4.89	4.98	4.91	4.90	4.74	0.10
Brown sugar	2.17	2.32	2.29	2.10	2.15	2.22	0.09
Molasses	1.67	1.34	1.23	1.27	1.31	1.23	0.07
Burnt[2,3]	1.13[ade]	1.36[b]	1.08[ac]	1.24[bde]	1.21[abe]	1.16[ae]	0.07
Aftertaste							
Sweet	3.17	3.13	3.25	3.05	3.08	3.21	0.09
Salty[5]	4.85[a]	5.02[a]	5.21[b]	5.03[a]	5.44[b]	4.79[a]	0.14
Smoked[5]	4.83[a]	5.03[a]	5.17[b]	4.80[a]	4.94[a]	4.93[a]	0.11
Meaty	3.69	3.73	3.83	3.75	3.77	3.67	0.09

[a–e]Means in the same row lacking a common superscript letter are different ($P < 0.05$), and describe the interactions noted below in footnotes 4 and 6.

[1]Main effect of fat level (0 < 4%; $P < 0.04$).

[2]CLA vs. LA ($P < 0.04$).

[3]Fat supplementation by LA interaction ($P < 0.09$).

[4]CLA vs. LA ($P < 0.10$).

[5]Fat supplementation by LA interaction ($P < 0.04$).

Table 4. Aroma, flavor, and aftertaste, as rated by a trained sensory panel, of loin samples from pigs consuming 0 or 4% supplemental fat combined with linoleic acid (LA) or CLA

	0% Supplemental fat		4% Yellow grease		4% Tallow		
Descriptor	LA	CLA	LA	CLA	LA	CLA	SEM
Aroma							
Oxidized	2.26	2.33	2.63	2.20	2.19	2.24	0.15
Cooked pork	6.21	5.80	5.77	5.82	5.98	5.96	3.01
Fat[1]	3.09	3.01	3.04	3.13	3.06	3.24	0.09
Metallic	2.83	2.75	2.79	2.81	2.77	2.85	0.11
Briny	1.84	1.92	1.91	1.84	1.86	1.77	0.07
Piggy[2,3]	1.69	1.96	1.64	1.53	1.78	1.80	0.12
Flavor	5.65	5.66	6.04	5.59	5.71	5.66	0.14
Oxidized	2.10	1.97	2.12	2.05	1.99	1.94	0.14
Cooked pork	6.22	6.30	6.21	6.25	6.14	6.19	0.13
Metallic	3.92	3.89	4.00	3.78	3.90	3.79	0.11
Astringent	3.22	3.16	3.08	3.15	3.16	2.93	0.09
Sweet	1.89	2.08	1.99	2.01	2.00	2.02	0.08
Sour[1,4]	1.85	1.72	1.64	1.55	1.70	1.52	0.10
Salty	1.69	1.68	1.81	1.68	1.68	1.69	0.07
Piggy	1.70	1.71	1.56	1.51	1.56	1.60	0.11
Aftertaste							
Oxidized[3]	3.26	3.10	3.22	3.23	3.05	3.01	0.11
Fat	4.07	3.98	3.88	3.93	3.94	3.95	0.19
Metallic	2.96	2.92	2.85	2.97	2.98	2.96	0.09
Astringent[2,5]	1.75	1.51	1.63	1.70	1.38	1.45	0.12

[1]CLA vs. LA ($P < 0.09$).
[2]Main effect of fat supplementation (0% supplemental fat vs. 4% yellow grease vs. 4% tallow; $P < 0.09$).
[3]Fat source effect (yellow grease vs. tallow; $P < 0.10$).
[4]Fat level effect (0 vs. 4%; $P < 0.03$).
[5]Fat source effect (yellow grease vs. tallow; $P < 0.05$).

intensity of salty aftertaste was greater when LA was combined with YG ($P < 0.07$) or tallow ($P < 0.01$) than LA alone, but supplemental fat combined with CLA was not different from CLA alone ($P < 0.02$).

For loin samples, fat supplementation appeared to reduce piggy flavor ($P < 0.09$). Sour flavor intensity was lower in samples from pigs consuming diets containing 4% supplemental fat ($P < 0.03$) and also tended to be lower in samples from pigs fed CLA than from those fed LA (LA; $P < 0.09$). Feeding CLA also resulted in a slight increase in the fat aroma of loin samples ($P < 0.09$). The aftertaste associated with lipid oxidation of loin samples was greater in samples from pigs fed 4% YG. Samples from animals fed 4% tallow tended to have a slightly lower intensity of astringent aftertaste ($P < 0.09$). Overall, dietary treatments appeared to affect loin sample aroma, flavor, and aftertaste to a lesser degree than bacon samples.

DISCUSSION

The effects of CLA on fat deposition, body composition, and lipid metabolism in humans and animals have been studied in depth, and recent studies on these effects and the possible mechanisms involved have been reviewed by Wang and Jones (2004). Supplemental fat and CLA have potential to affect pork quality. We and others have measured changes in fatty acid profiles when supplemental fats (Averette Gatlin et al., 2002, 2003; Gatlin et al., 2002) or CLA (Weigand et al., 2002; Corino et al., 2003; Migdal et al., 2004) were fed. Dietary supplementation of YG to pigs in our study resulted in an increase in the LA concentration in belly fat samples (Averette Gatlin et al., 2002) and could increase the opportunity for lipid oxidation in pork products, specifically bacon. Dugan et al. (2004) reviewed 18 studies in which CLA was fed to pigs and found a reduction in carcass fat content ranging from 6.2 to 25% and that CLA concentration in tissue was highly enriched in 7 of those studies. However, there was no mention of palatability or taste panel results from any of the studies in this review. Recent papers published examining the effects of CLA on pork quality have primarily examined the impact of CLA on loin muscle quality and palatability (Dugan et al., 1999; Weigand et al., 2001, 2002) with no information available on the impact of CLA supplementation on the organoleptic characteristics of bacon.

It is expected that changes in carcass composition, fatty acid composition, or both may lead to differences in palatability and acceptance of pork products. One example is the increased opportunity for rancidity in products containing greater amounts of unsaturated fatty acids (Melton, 1990). Cameron and Enser (1991) compared eating quality traits with intramuscular fatty acid composition. In general, greater concentrations of MUFA and SFA were associated with higher panel scores for overall acceptability as well as tenderness, juiciness, and flavor. Poorer scores for these traits resulted from pork with higher concentrations of PUFA.

Further, Miller et al. (1990) determined that canola oil supplementation led to increases in linoleic acid and off-flavors, which were due to oxidation. In the current study, supplementation of CLA and tallow led to lower concentrations of C18:2 (Averette Gatlin et al., 2002). However, there were minimal differences in taste panel acceptability of loin chops. Larick et al. (1992) determined the content of volatile compounds in pork after feeding several combinations of safflower oil and tallow. They noted significant increases in the LA content of pork from pigs fed diets high in C18:2 and increased concentrations of several volatiles associated with increased oxidation activity. However, these changes had minimal impact on the flavor of cooked, fresh meat.

Because bacon contains a greater amount of fat than other pork products, it may be more susceptible to development of rancidity (Rogers and Etzler, 2000). Processing, packaging, and storage conditions may also have effects on the shelf life. Rogers and Etzler (2000) determined that overall panel ratings were acceptable for vacuum-packaged products and totally unacceptable for sliced-slab (not vacuum-packaged), frozen products, regardless of supplemental dietary fat source or inclusion level. In that same study, the fatty acid composition was changed because of various dietary fat sources. In addition minor differences were noted in several attributes including saltiness and flavor intensity. But these differences were small and were not considered to be of practical importance.

Dugan et al. (1999) evaluated the effects of CLA feeding on pork quality and palatability characteristics. Loin chops were evaluated by a 6-member panel for tenderness, flavor, and juiciness. The panel did not detect differences in these characteristics in samples from pigs fed CLA or a sunflower oil control diet. Weigand et al. (2001) noted that the sensory characteristics (tenderness, juiciness, and flavor intensity) of samples from stress-genotype pigs fed diets containing 0.75% CLA were not different. They found similar results in a study evaluating the duration of feeding 0.75 to 1.25% CLA (Weigand et al., 2002). Corino et al. (2003) evaluated dry-cured hams from pigs supplemented with 0 to 0.5% CLA and found that most sensory characteristics were unchanged. In contrast, Migdal et al. (2004) noted a difference in the intensity and the quality of flavor from a sensory analysis of eating quality of loin samples from pigs fed 2% CLA. Associated with the difference in flavor, the concentrations of unsaturated fatty acids and PUFA were lower in samples from pigs fed CLA (Migdal et al., 2004).

We are unaware of any studies that have evaluated the combined effects of CLA and supplemental fat on sensory attributes of bacon. The descriptive analysis developed by our panel of bacon and loin chop samples was more in-depth than many other published studies that have looked at only a few descriptors or evaluated samples with difference testing. The differences that our panel detected in salty flavor intensity or intensity of salty aftertaste of bacon from pigs fed LA from corn oil or LA combined with YG, respectively, might have been due to the differences in fatty acid composition or overall fat composition. If the total amount of fat in the bacon or its fatty acid composition altered the retention of brine ingredients, such as salt or nitrites, it would have the potential to affect flavor. The increased intensity of fat flavor and reduced lean flavor attributable to CLA feeding might have occurred for similar reasons. The increase in the aftertaste associated with lipid oxidation in longissimus samples from pigs fed 4% YG is likely due to changes in fatty acid composition discussed previously (Averette Gatlin et al., 2002). Overall, the numerical differences detected by the panel were minimal. These small differences indicate that consumer acceptance of bacon and pork products from pigs fed supplemental fat and CLA would not likely differ from commodity pork products.

IMPLICATIONS

This study provides a detailed description of the organoleptic characteristics of bacon and loin samples from pigs fed conjugated linoleic acid combined with tallow or yellow grease. Pork products that differ in linoleic acid content due to variation in supplemental fat source and level may have an increased opportunity for lipid oxidation. Limited information is available describing how consumers define desirable flavors and characteristics in bacon products. Such research is important because consumer acceptability is essential, and shifting fat quality to improve processing characteristics should not alter the consumer satisfaction of the products. Based on this study, our trained taste panel identified minor differences (approximately 1 point on a 14 point scale) in flavor of bacon and pork from pigs fed conjugated linoleic acid that would not likely be detectable by consumers.

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