Effect of Sorghum Dried Distillers Grains with Solubles on Composition, Retail Stability, and Sensory Attributes of Ground Pork from Barrows and Gilts[1]

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Summary

A total of 288 finishing pigs (PIC TR4 × 1050, initially 129.6 lb) were utilized as part of a 73-d feeding study to determine the effects of sorghum dried distillers grains with solubles (S-DDGS) in sorghum- or corn-based diets on ground pork quality. The dietary treatments included sorghum-based diets with 0, 15, 30, or 45% S-DDGS, a sorghum-based diet with 30% corn DDGS (C-DDGS), and a corn-based diet with 30% C-DDGS. Shoulders from 24 barrow and 24 gilt carcasses were ground, packaged, and evaluated for proximate and fatty acid composition, iodine value (IV), objective color and oxidation shelf-life, and sensory attributes. Finishing diet and gender did not interact to affect composition, fatty acid profile, color, or oxidative rancidity ($P > 0.05$). Pork from gilts contained less fat and more moisture ($P < 0.001$), was less saturated with a greater IV and total percentage of polyunsaturated fatty acids ($P < 0.01$), and was also darker ($P < 0.001$) and more red ($P = 0.004$) than pork from barrows. Gender did not affect ($P > 0.05$) total color change from 0 to 120 h, oxidative rancidity, or sensory attributes of ground pork. Finishing diet had no effect on total fat, moisture, or protein composition. Increasing S-DDGS resulted in a linear ($P < 0.001$) decrease in saturated and monounsaturated fatty acids (MUFA) and an increase ($P < 0.01$) in polyunsaturated fatty acids (PUFA) and pork IV. Pork from pigs fed 30% S-DDGS had a greater percentage of MUFA, a lower percentage of PUFA, and reduced IV compared with pork from pigs fed 30% C-DDGS. Diet did not affect oxidative rancidity ($P = 0.37$) or objective color CIE L* (brightness), a* (redness), or b* (yellowness) values ($P \geq 0.09$), but was shown to influence total color change ($P = 0.01$), with pork from pigs fed sorghum grain and 30% S-DDGS showing less total change than all other dietary treatments. All pork products were characterized with similar sensory descriptors.

Overall, increasing S-DDGS during finishing resulted in ground pork with a more unsaturated fatty acid profile. Utilization of S-DDGS compared with an equal level of C-DDGS resulted in pork with a more saturated fatty acid profile and reduced IV; however, product differences were not carried through to alter oxidative rancidity or sensory attributes.

Key words: DDGS, gender, pork quality, sensory attributes, sorghum

Introduction

Dried distillers grains with solubles, largely processed from corn (C-DDGS), have been a popular feed ingredient in swine diets in the past decade due to their increas-

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ing availability and the opportunity for diet cost savings. The use of sorghum grains in ethanol has grown to include 30 to 35% of the domestically grown sorghum, making their role in livestock production of interest to those in plains states such as Kansas (USCP, 2011[2]). In general, DDGS are fed at 20 to 30% of the diet because many studies have shown this level is not detrimental to growth performance, but feeding at these levels has been shown to hinder pork quality and result in a more unsaturated fatty acid profile and therefore increases in iodine value (IV), PUFA such as linoleic acid (C18:2), and total percentage PUFA. This leads to softer fat, fabrication difficulties, reduced bacon yields, unattractive products, and reduced shelf-life (NPPC, 2000[3]). Although many diets fed are corn-soybean meal-based, Benz et al. (2011[4]) found pigs fed sorghum-based diets to have a lower IV than pigs fed corn. Because sorghum grains are largely recognized as a replacement for corn in finishing diets that does not affect growth performance, they may offer an opportunity to assist in the control of pork fat quality issues and allow for the inclusion of DDGS at higher, more economically preferred levels. Additionally, the work detailing the influence of DDGS on consumer-evaluated quality issues such as color and sensory attributes is not extensively detailed. Therefore, the objective of this study was to determine the effects of increasing sorghum DDGS (S-DDGS) in sorghum- or corn-based diets on ground pork composition, fatty acid profile, and sensory attributes as well as retail display objective color and oxidative rancidity.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved procedures used in this experiment. The K-State Institutional Review Board accepted sensory panel studies used in this experiment.

A total of 288 finishing pigs (PIC TR4 × 1050, initially 129.6 lb) were utilized as part of a 73-d feeding study to determine the effects of increasing S-DDGS in sorghum- or corn-based diets on finishing pig performance. Results of the growth performance portion of the trial can be found on page 182 of this report (see "The Effects of Sorghum Dried Distillers Grains with Solubles on Finishing Pig Growth Performance, Carcass Characteristics, and Fat Quality"). The dietary treatments included sorghum-based diets with S-DDGS included at 0, 15, 30, or 45%; a sorghum-based diet with 30% C-DDGS; and a corn-based diet with 30% C-DDGS. Our results report the effects of sorghum DDGS or corn DDGS on the resulting ground pork composition, sensory attributes, and retail display life.

At the conclusion of the feeding trial, the heaviest barrow and gilt were selected from each pen with 1 pig humanely harvested on each of 2 dates at the K-State Meat Laboratory. Pigs were allocated to harvest dates so an equal number of barrows and gilts came from each diet.

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[2] USPC (United Sorghum Checkoff Program). 2011. Sorghum 101. Accessed June 3, 2011. http://www.sorghumcheckoff.com/sorghum-101.

[3] NPPC. 2000. Pork Composition & Quality Assessment Procedures. Natl. Pork Prod. Counc., Des Moines, IA.

[4] Benz, J. M., M. D. Tokach, S. S. Dritz, J. L. Nelssen, J. M. DeRouchey, R. C. Sulabo, and R. D. Goodband. 2011. Effects of increasing choice white grease in corn- and sorghum- based diets on growth performance, carcass characteristics, and fat quality characteristics of finishing pigs. J. Anim. Sci. 89:773-782.

A total of 48 carcasses were used for production of ground pork to be utilized in all subsequent evaluations. Twenty-four pigs were randomly selected from each of the 2 harvest dates, so within a single harvest date a total of 4 pigs were from each diet (2 barrows and 2 gilts), with each pig sourced from a different original finishing pen.

Approximately 48 h postmortem, Institutional Meat Purchase Specifications (IMPS) No. 403 pork shoulders were separated from the right and left carcass halves, fabricated to remove bones, trimmed to an external average fat thickness of 0.25 in., and placed in storage (< 37°F). Approximately 72 h post mortem, shoulders were simultaneously trimmed of any noticeable blood splash then ground to a diameter of 0.5 in., mixed thoroughly by hand, and ground to a final diameter of 0.13 in. Final product grind temperature ranged from 40 to 43°F. Following the final grind, pH was recorded for each meat block before 7 1.0-lb packages were prepared for retail display; 2.0 lb of product was removed for sensory evaluation, vacuum-packaged, and stored (-20°F), and 1.0 lb was removed and submitted to the K-State Analytical Services Lab for compositional analysis.

For composition, approximately 0.5 lb of each sample was frozen in liquid nitrogen and pulverized. Duplicate samples were evaluated for moisture and crude fat (AOAC Official Method: PVM-1:2003 Meat), CP (AOAC Official Method: 990.03), and fatty acid profile (Sukhija and Palmquist, 1988[5]). Fatty acid profile data are reported as a percentage of the total fatty acid content. Additionally, iodine value (IV) was calculated according to (AOCS, 1998[6]) using: [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.72, where brackets indicate concentration.

Retail display packages were prepared by placing 1.0 lb of product on a stryrofoam tray with an absorbent pad and overwrapping with a polyvinyl chloride (PVC) film. Immediately after packaging, all products were removed from light and held below 40°F for no more than 1 h before display placement.

During display, 2 identical, open-top retail cases (Model DMF8, Tyler Refrigeration Corp., Niles, MI) were used. One case was equipped with fluorescent lighting (Sylvania/F032/835/Eco, 3500K; Osram-Sylvania, Danvers, MA) and the other with LED lighting (Energyled E1N5KLHC3-S4, 3500K; Altair Exchange Corp., Canoga Park, CA). Both sets of lights were of an equivalent color temperature (3,500 K) and were adjusted above the cases to emit a light intensity of 2,152 ± 108 lux. Case temperature during display ranged from 33 to 45°F.

From the 7 packages of ground pork retained from each pig, 1 was randomly allocated to be sampled at 0 h and not placed in retail display, with the other 6 randomly split between the 2 cases. Specifically, from the 3 samples within each case, 1 package was evaluated for objective color at 12 and 24 h, then removed; the second was evaluated at 36, 48, 60 and 72 h, then removed; and the third was evaluated at 84, 96, 108, and 120 h of display at which point it was removed. Remaining packages were rotated after each

[5] Sukhija, P. S., and D. L. Palmquist. 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. J. Agric. and Food Chem. 36:1202-1206.

[6] AOCS. 1998. Official Methods and Recommended Practices of the AOCS. 5th ed. Am. Oil Chem. Soc., Champaign, IL.

evaluation. CIE L*, a*, and b* values from a spectral reflectance range of 400 to 700 nm were obtained using a HunterLab Miniscan EZ colorimeter (Model 4500L, 1.25-in.-diameter aperture, 10° standard observer, Illuminant A10, Hunter Associates Laboratory, Inc., Reston, VA). Additionally, total color change from 0 to 120 h was calculated according to Minolta (1998[7]) as follows: $\sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]}$.

Oxidative rancidity was evaluated on all retail packages after frozen storage (-112°F) following the conclusion of the second display repetition. Thiobarbituric acid-reactive substances (TBARS) were performed as described by Buege and Aust (1978[8]) and modified according to the American Meat Science Association (AMSA). Duplicate 0.02-oz samples were weighed and thoroughly mixed with 2.5 mL of thiobarbituric acid (TBA) stock solution containing 0.375% TBA, 15% trichloroacetic acid, and 0.25N hydrochloric acid. Samples, including a blank standard tube containing only 2.5 mL of TBA stock solution, were then boiled (212°F), cooled in tap water, and centrifuged at 5000 × g. Samples were then filtered and the supernatant absorbance was read at 532 nm (A_{532}) against the blank solution with a spectrophotometer. TBARS values (mg malonaldehyde (MDA)/kg of meat) were calculated using an extraction coefficient of 156,000 M^{-1} cm^{-1} (Sinhuber and Yu, 1958[9]) as follows:

$$\text{TBA(mg/kg)} = \text{sample } A_{532} \times \frac{\text{1 M chromagen}}{156{,}000} \times \frac{\text{1 mol/L}}{M} \times \frac{\text{0.003 L}}{\text{0.5 g meat}} \times \frac{\text{72.07 g MDA}}{\text{mole}} \times \frac{\text{1000 mg}}{g} \times \frac{\text{1000 g}}{kg}$$

Sensory analysis utilized 6 to 8 trained panelists per session. Ground pork from each of the 24 pigs selected within a harvest date was randomly allocated to 1 of 4 panels such that 6 pigs were evaluated during a single session, 1 from each dietary treatment and 3 of each gender. After thawing, four 0.25-lb, 0.5-in.-thick ground pork patties (GPPs) were formed and simultaneously cooked to an internal temperature of 160°F. Cooked GPPs from a single pig were each cut into 6 equal pieces and held in individual double-boiler pans during sampling. Panelists were asked to evaluate each GPP sample on a numerical scale from 1 to 8 for the following attributes, scoring to the 0.5 increment: Pork aroma (1= *extremely weak*, 8 = *extremely strong*); off-aroma (1= *none*, 8 = *abundant*); pork flavor (1= *extremely bland*, 8 = *extremely intense*); juiciness (1= *extremely dry*, 8= *extremely juicy*); texture (1= *extremely soft*, 8 = *extremely hard*); off-flavor (1= *none*, 8 = *abundant*).

Data analyses were conducted utilizing the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Color and oxidative rancidity data were analyzed as a randomized complete block with a split-plot. Pig served as the whole-plot experimental unit, and package served as the split-plot experimental unit. Sensory data were analyzed as a randomized incomplete block with pig serving as the experimental unit. Data for pH, moisture, crude fat, CP, and percentage total fatty acid profile were analyzed as a randomized complete block with pig serving as the experimental unit. Main and

[7] Minolta. 1998. Precise Color Communication: Color Control from Perception to Instrumentation. Minolta Corp., Ramsey, NJ.

[8] Buege, J. A., and Aust, S. D. 1978. Microsomal lipid peroxidation. Methods in Enzymology, 52, 306.

[9] Sinhuber, R. O., and Yu, T. C. 1958. 2-Thiobarbituric acid method for the measurement of rancidity in fishery products. II. The quantitative determination of malonaldehyde. Food Tech. 12(1):9-12.

interactive effects for diet and gender were interpreted as significant when differences resulted in a P-value < 0.05.

Results and Discussion

No diet × gender interactive effects were observed for ground pork percentage moisture, protein, or fat, fatty acid profile, or ultimate pH. Additionally, the inclusion and increase of S-DDGS in the diet had no effect ($P > 0.05$) on percentage fat, moisture, or protein (Table 1). Finishing diet was shown to significantly affect levels of several fatty acids (Table 2), calculated as a percentage of the total fatty acid content. Of those fatty acids found to be influenced by diet ($P < 0.05$), pork from pigs finished on both diets containing 30% C-DDGS, had equivalent ($P > 0.05$) levels of all fatty acids, ratios, and IV with the exception of myristic acid (C14:0), which was slightly higher ($P < 0.05$) in pork from the sorghum grain-based diet. This suggests that use of sorghum grain does not result in a fatty acid profile advantage compared with corn grain when finishing with an equal level of C-DDGS. Next, we compared diets containing S-DDGS vs. C-DDGS at 30%. In this case, ground pork from pigs fed with S-DDGS had a higher ($P < 0.0001$) percentage of oleic acid (C18:1n9c) and total percentage of MUFA, and a lower ($P < 0.001$) percentage of total C18:2, percentage PUFA, PUFA:saturated fatty acid (SFA) ratio, and a lower IV than pork from pigs finished with 30% corn DDGS. Linear trends ($P < 0.05$) in conjunction with an increasing percentage of S-DDGS from 0 to 45% were observed for many fatty acids, including % increases in linoleic (C18:2n6c), α-Linolenic acid (C18:3n3), eicosadienoic acid, (C20:2), total PUFA, and IV, as well as percentage decreases in palmitic acid (C16:0), palmitoleic acid (C16:1), oleic acid (C18:1n9c), vaccenic acid (C18:1n7), total SFAs, and total MUFA. Overall, increasing S-DDGS during finishing resulted in a more unsaturated fatty acid profile. Furthermore, utilization of S-DDGS compared with an equal amount of C-DDGS results in pork with a more desirable saturated fatty acid profile.

Gender also affected composition, with ground pork from barrows containing more fat and less moisture ($P < 0.001$) than product from gilts (Table 1). Barrows also contained a more saturated fatty acid profile compared with gilts; pork from barrows contained a higher ($P \leq 0.01$) percentage of palmitic acid (C16:0), oleic acid (C18:1n9c), and total MUFA, as well as a lower ($P \leq 0.01$) percentage of linoleic acid (C18:2n6c), total C18:2 fatty acids, α-Linolenic acid (C18:3n3), total PUFA, and IV (Table 3). In general, pork from barrows was more saturated than ground pork sourced from gilts. Pigs with a greater amount of fat deposition have been shown to have a reduced carcass fat IV (Bergstrom et al., 2010[10]). Because barrows were fatter than gilts, as expected, these findings agree with the expectation that pork from barrows should be more saturated than product from gilts.

No 2- or 3-way interactive effects were observed between retail display hour, finishing diet, and gender regarding ground pork color or oxidation during 120 h of retail display. As expected, a linear ($P < 0.0001$) decrease occurred over time (Table 4) in ground pork L*, a*, and b*. Additionally, ground pork oxidation according to TBARS was dependent on h of storage, with the least oxidation observed at 24 h and the most at 120 h. Both finishing diet and gender were found to have no effect ($P = 0.37$ and 0.08, respectively) on overall ground pork oxidation (Table 5), suggesting that the use of sorghum grain

[10] Bergstrom et al., Swine Day 2010, Report of Progress 1038, pp. 119-135.

and the use of S-DDGS does not alter final product oxidation when compared with corn grain and C-DDGS. Although finishing diet did not influence CIE L*, a*, or b* values of ground pork, diet was found to influence ($P = 0.01$) total color change (ΔE), with pork from pigs fed sorghum grain and 30% S-DDGS having a more preferred, lower total color change over the period of retail display when compared with all other diets. Compared with corn grain and the use of C-DDGS, sorghum and S-DDGS does not alter retail color life. Additionally, gender of pigs did not affect ΔE from 1 to 120 h; however, pork from gilts was found to be darker ($P < 0.001$), more red (P = 0.004), and slightly less yellow.

In sensory attributes, diet was shown to interact with gender to affect ($P = 0.01$) only pork aroma (Table 6). Although significant, interactive pork aroma mean scores ranged only from 5.4 to 5.8, categorizing all products as having a similar, "slightly strong" pork aroma. Independently, gender had no effect on sensory attributes, whereas diet was found to influence only texture and off-aroma ($P \leq 0.05$; Table 7). Ground pork patties from those pigs finished on 0, 15, 30, and 45% S-DDGS were described as "slightly soft" for texture, and GPPs from pigs finished on diets containing 30% C-DDGS were scored only slightly lower and categorized as "moderately soft." Pork sourced from all finishing diets was evaluated as having no off-flavor, with GPPs from pigs fed 15 and 30% S-DDGS having the least off-flavor. Overall, although some small significant differences in sensory attributes were noted, the use of sorghum grain in addition to the inclusion of 0 to 45% S-DDGS when compared with corn grain or C-DDGS did not alter the flavor profile of ground pork patties. Product from all pigs was predominantly described as having a "slightly strong" pork aroma with no off-aroma, a "slightly intense" pork flavor with no off-flavor, and being "slightly" juicy with a "slightly soft" texture.

In summary, fatty acid profile differences were noted according to the inclusion and increase of S-DDGS in the swine finishing diet; however, these alterations did not carry through to affect final ground pork quality attributes concerning oxidative rancidity and trained panel sensory analysis. We conclude that sorghum grain and S-DDGS can be fed to result in high-quality ground pork.

Table 1. Effect of dietary grain and dried distillers grains with solubles (DDGS) source or gender on ground pork composition[1]

	Diet											
Grain source	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
DDGS source	-	Sorghum	Sorghum	Sorghum	Corn	Corn		Gender			*P*-value	
DDGS level	0%	15%	30%	45%	30%	30%	SE	Barrow	Gilt	SE	Diet	Gender
Item												
Moisture, %	62.2	63.4	62.1	63.9	61.5	62.6	0.94	60.7	64.6	0.69	0.27	< 0.001
CP, %	18.6	18.8	18.0	18.8	18.3	18.1	0.28	18.1	18.8	0.16	0.18	< 0.01
Crude fat, %	17.9	16.8	18.8	16.1	19.2	18.0	1.15	20.3	15.3	0.81	0.25	< 0.001
pH	5.8	5.9	6.0	5.9	5.9	5.9	0.06	5.9	5.9	0.05	0.46	0.46

[1] Ground pork was made from both shoulders from each of 48 pigs, 8 per dietary treatment (4 barrows and 4 gilts).

Table 2. Effect of dietary grain and dried distillers grains with solubles (DDGS) source on ground pork fatty acid profile[1]

	Diet							*P*-value	
Grain source	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn			
DDGS source	-	Sorghum	Sorghum	Sorghum	Corn	Corn			
Item[2] DDGS level	0%	15%	30%	45%	30%	30%	SE	Diet	Linear[3]
Myristic acid (C14:0), %	1.46	1.42	1.42	1.36	1.43	1.35	0.02	< 0.05	0.01
Palmitic acid (C16:0), %	24.60	24.00	24.13	23.04	23.78	23.13	0.23	< 0.001	< 0.0001
Palmitoleic acid (C16:1), %	2.77	2.72	2.43	2.35	2.40	2.31	0.10	< 0.01	0.001
Margaric acid (C17:0), %	0.44	0.45	0.47	0.49	0.52	0.46	0.03	0.29	0.14
Stearic acid (C18:0), %	12.78	12.34	12.72	11.79	12.29	12.04	0.31	0.20	0.07
Oleic acid (C18:1n9c), %	40.83	39.68	39.40	38.33	37.71	38.05	0.40	< 0.0001	< 0.001
Vaccenic acid (C18:1n7), %	4.00	3.91	3.65	3.62	3.48	3.44	0.09	< 0.0001	< 0.001
Linoleic acid (C18:2n6c), %	9.40	11.39	11.89	14.71	14.25	15.11	0.54	< 0.0001	< 0.0001
Total C18:2 fatty acids, %[4]	9.54	11.56	12.03	14.87	14.40	15.24	0.55	< 0.0001	< 0.0001
α-Linolenic acid (C18:3n3), %	0.57	0.63	0.61	0.77	0.63	0.64	0.03	0.01	< 0.001
Arachidic acid (C20:0), %	0.20	0.21	0.21	0.20	0.21	0.20	0.01	0.83	0.92
Eicosenoic acid (C20:1), %	0.76	0.78	0.78	0.78	0.75	0.77	0.03	0.95	0.58
Eicosadienoic acid (C20:2), %	0.48	0.57	0.59	0.69	0.69	0.73	0.03	< 0.0001	< 0.0001
Arachidonic acid (C20:4n6), %	0.10	0.11	0.10	0.13	0.10	0.11	0.01	0.04	0.02
Other fatty acids, %	1.47	1.62	1.46	1.58	1.59	1.54	0.07	0.38	0.55
Total SFA, %[5]	39.88	38.88	39.36	37.32	38.68	37.61	0.45	< 0.01	< 0.001
Total MUFA, %[6]	48.99	47.76	46.88	45.74	45.00	45.17	0.49	< 0.0001	< 0.0001
Total PUFA, %[7]	11.13	13.37	13.76	16.94	16.32	17.22	0.62	< 0.0001	< 0.0001
UFA:SFA, ratio[8]	1.51	1.58	1.54	1.68	1.59	1.66	0.03	< 0.01	< 0.01
PUFA:SFA, ratio[9]	0.28	0.35	0.35	0.46	0.42	0.46	0.02	< 0.0001	< 0.0001
Iodine value (IV)[10]	60.2	62.8	62.7	67.1	65.3	66.9	0.80	< 0.0001	< 0.0001

[1] Ground pork was made from both shoulders of each of 48 pigs, 8 per dietary treatment (4 barrows and 4 gilts).
[2] All items calculated as a percentage of the total fatty acid content.
[3] Increase of sorghum DDGS from 0 to 45%.
[4] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% C18:2, 10t12c] + [% C18:2, 9c11c] + [% C18:2, 9t11t].
[5] Total saturated fatty acids = [% C10:0] + [% C11:0] + [% C12:0] + [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C24:0].
[6] Total monounsaturated fatty acids = [% 14:1] + [% 15:1] + [% 16:1] + [% 17:1] + [% 18:1n9t] + [% 18:1n9c] + [% 18:1n7] + [% 20:1] + [% 24:1].
[7] Total polyunsaturated fatty acids = [% 18:2n6t] + [% 18:2n6c] + [% C18:2 9c,11t] + [% C18:2 10t,12c] + [% C18:2 9c,11c] + [% C18:2 9t,11t] + [% 18:3n6] + [% 18:3n3] + [% 20:2] +[% 20:3n6] + [% 20:4n6] + [% 20:5n3] + [% 22:5n3] + [% 22:5n6].
[8] UFA:SFA ratio = [Total MUFA+ Total PUFA] / Total SFA.
[9] PUFA:SFA ratio = Total PUFA / Total SFA.
[10] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785 + [% C22:1] × 0.723.

Table 3. Effect of gender on ground pork fatty acid profile[1]

	Gender			
Item[2]	Barrow	Gilt	SE	P-value
Myristic acid (C14:0), %	1.43	1.39	0.01	0.04
Palmitic acid (C16:0), %	24.14	23.42	0.13	< 0.001
Palmitoleic acid (C16:1), %	2.58	2.41	0.06	0.04
Margaric acid (C17:0), %	0.47	0.48	0.02	0.66
Stearic acid (C18:0), %	12.29	12.36	0.18	0.79
Oleic acid (C18:1n9c), %	39.44	38.56	0.23	0.01
Vaccenic acid (C18:1n7), %	3.73	3.64	0.06	0.15
Linoleic acid (C18:2n6c), %	12.00	13.59	0.31	< 0.001
Total C18:2 fatty acids, %[3]	12.15	13.73	0.32	< 0.01
α-Linolenic acid (C18:3n3), %	0.60	0.68	0.02	0.01
Arachidic acid (C20:0), %	0.20	0.21	0.01	0.73
Eicosenoic acid (C20:1), %	0.79	0.75	0.02	0.14
Eicosadienoic acid, (C20:2), %	0.59	0.66	0.02	< 0.01
Arachidonic acid (C20:4n6), %	0.10	0.12	0.01	< 0.01
Other fatty acids, %	1.49	1.60	0.04	0.03
Total SFA, %[4]	38.95	38.29	0.26	0.08
Total MUFA, %[5]	47.17	46.01	0.29	0.01
Total PUFA, %[6]	13.87	15.71	0.36	0.001
UFA:SFA, ratio[7]	1.57	1.62	0.18	0.08
PUFA:SFA, ratio[8]	0.36	0.41	0.01	< 0.01
Iodine value (IV)[9]	63.2	65.2	0.5	< 0.01

[1] Ground pork was made from both shoulders of each of 48 pigs, 24 barrows and 24 gilts.
[2] All items calculated as a percentage of the total fatty acid content.
[3] Total C18:2 fatty acids = [% C18:2n6t] + [% C18:2n6c] + [% C18:2, 9c11t] + [% C18:2, 10t12c] + [% C18:2, 9c11c] + [% C18:2, 9t11t].
[4] Total saturated fatty acids = [% C10:0] + [% C11:0] + [% C12:0] + [% C14:0] + [% C15:0] + [% C16:0] + [% C17:0] + [% C18:0] + [% C20:0] + [% C21:0] + [% C22:0] + [% C24:0].
[5] Total monounsaturated fatty acids = [% 14:1] + [% 15:1] + [% 16:1] + [% 17:1] + [% 18:1n9t] + [% 18:1n9c] + [% 18:1n7] + [% 20:1] + [% 24:1].
[6] Total polyunsaturated fatty acids = [% 18:2n6t] + [% 18:2n6c] + [% C18:2 9c,11t] + [% C18:2 10t,12c] + [% C18:2 9c,11c] + [% C18:2 9t,11t] + [% 18:3n6] + [% 18:3n3] + [% 20:2] + [% 20:3n6] + [% 20:4n6] + [% 20:5n3] + [% 22:5n3] + [% 22:5n6].
[7] UFA:SFA ratio = [Total MUFA+ Total PUFA] / Total SFA.
[8] PUFA:SFA ratio = Total PUFA / Total SFA.
[9] Iodine value = [% C16:1] × 0.95 + [% C18:1] × 0.86 + [% C18:2] × 1.732 + [% C18:3] × 2.616 + [% C20:1] × 0.785 + [% C22:1] × 0.723.

Table 4. Ground pork oxidation and color from 0 to 120 h of retail display[1]

	Hour												*P*-value	
Item	0	12	24	36	48	60	72	84	96	108	120	SE	Hour	Linear
TBARS[2]														
(mg MDA/ kg)[3]	0.374	-	0.269	-	-	-	0.377	-	-	-	0.492	0.039	< 0.0001	< 0.0001
Objective color														
CIE L*[4]	63.4	61.8	61.9	61.0	60.3	59.8	59.4	59.7	59.8	59.2	60.6	0.61	< 0.0001	< 0.0001
CIE a*[5]	22.5	20.1	19.1	18.1	17.9	17.7	17.2	16.6	16.0	15.8	15.1	0.12	< 0.0001	< 0.0001
CIE b*[6]	19.0	18.0	17.5	17.7	17.4	17.6	17.5	17.5	17.2	17.3	16.6	0.23	< 0.0001	< 0.0001

[1] Two sets of 3 packages from each of 48 pigs, 8 per diet (4 barrows and 4 gilts) were held in retail display for 5 d (120 h).

[2] Thiobarbituric acid-reactive substances; a measure of oxidative rancidity.

[3] Unit = mg of malonaldehyde per kilogram of meat; higher values indicates greater oxidative rancidity.

[4] Measure of lightness; 0 = black, 100 = white.

[5] Higher positive values indicate greater redness; negative values indicate greenness.

[6] Higher positive values indicate greater yellowness; negative values indicate blueness.

Table 5. Effect of dietary grain and dried distillers grains with solubles (DDGS) source or gender on ground pork oxidation and color during retail display[1]

	Diet							Gender			*P*-value	
	A	B	C	D	E	F						
Grain source	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
DDGS source	-	Sorghum	Sorghum	Sorghum	Corn	Corn						
DDGS level	0%	15%	30%	45%	30%	30%	SE	Barrow	Gilt	SE	Diet	Gender
Item												
TBARS[2]												
(mg MDA/ kg)[3]	0.345	0.375	0.361	0.383	0.403	0.401	0.042	0.394	0.362	0.04	0.37	0.08
Objective color												
CIE L*[4]	60.1	60.2	61.0	60.5	61.1	60.8	0.75	61.4	59.8	0.62	0.66	< 0.0001
CIE a*[5]	17.7	17.5	18.3	18.1	17.7	17.7	0.20	17.6	18.1	0.11	0.09	0.004
CIE b*[6]	17.5	17.5	17.9	17.5	17.6	17.5	0.24	17.7	17.4	0.22	0.11	0.01
ΔE[7]	8.7	8.9	7.3	8.5	8.9	9.3	0.92	8.7	8.4	0.88	0.01	0.30

[1] Two sets of 3 packages from each of 48 pigs, 8 per diet (4 barrows and 4 gilts) were held in retail display for 5 d (120 h).
[2] Thiobarbituric acid-reactive substances; a measure of oxidative rancidity.
[3] Unit = mg of malonaldehyde per kg of meat; higher values indicates greater oxidative rancidity.
[4] Measure of lightness; 0 = black, 100 = white.
[5] Higher positive values indicate greater redness; negative values indicate greenness.
[6] Higher positive values indicate greater yellowness; negative values indicate blueness.
[7] Total color change during retail display from h 0 to 120 = $\sqrt{[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]}$.

Table 6. Effect of dietary grain and dried distillers grains with solubles (DDGS) source with gender on ground pork sensory attributes[1]

Grain source	Sorghum		Sorghum		Sorghum		Sorghum		Sorghum		Corn			
DDGS source	-		Sorghum		Sorghum		Sorghum		Corn		Corn			
DDGS level	0%		15%		30%		45%		30%		30%			
Gender[2]	B	G	B	G	B	G	B	G	B	G	B	G	SE	*P*-value
Sensory attribute														
Pork aroma[3]	5.8	5.6	5.4	5.7	5.7	5.6	5.8	5.7	5.7	5.8	5.5	5.8	0.10	0.01
Off-aroma[4]	1.1	1.2	1.1	1.2	1.1	1.2	1.2	1.2	1.3	1.1	1.5	1.2	0.11	0.28
Pork flavor[5]	5.5	5.3	5.4	5.5	5.6	5.7	5.8	5.4	5.5	5.4	5.4	5.5	0.17	0.28
Juiciness[6]	5.5	5.3	5.4	5.8	5.5	5.8	5.8	5.5	5.7	5.9	5.7	5.7	0.15	0.21
Texture[7]	4.3	4.3	4.1	4.0	4.1	4.0	4.1	4.2	4.0	3.8	3.8	3.9	0.13	0.86
Off-flavor[8]	1.3	1.2	1.0	1.3	1.2	1.2	1.4	1.5	1.5	1.3	1.6	1.3	0.10	0.24

[1] Ground pork from each of 48 pigs, 8 per diet (4 barrows and 4 gilts), were analyzed during 8 trained panel sessions.
[2] Gender: B = barrow, G = gilt.
[3] Scale of 1-8: 1= extremely weak, 8 = extremely strong.
[4] Scale of 1-8: 1= none, 8 = abundant.
[5] Scale of 1-8: 1= extremely bland, 8 = extremely intense.
[6] Scale of 1-8: 1= extremely dry, 8= extremely juicy.
[7] Scale of 1-8: 1= extremely soft, 8 = extremely hard.
[8] Scale of 1-8: 1= none, 8 = abundant.

Table 7. Effect of dietary grain and dried distillers grains with solubles (DDGS) source or gender on ground pork sensory attributes[1]

	Diet							Gender			*P*-value	
	A	B	C	D	E	F						
Grain source	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Corn						
DDGS source	-	Sorghum	Sorghum	Sorghum	Corn	Corn						
DDGS level	0%	15%	30%	45%	30%	30%	SE	Barrow	Gilt	SE	Diet	Gender
Sensory attribute												
Pork aroma[2]	5.7	5.6	5.6	5.8	5.7	5.7	0.09	5.7	5.7	0.08	0.09	0.41
Off-aroma[3]	1.1	1.1	1.2	1.2	1.2	1.3	0.09	1.2	1.2	0.07	0.29	0.69
Pork flavor[4]	5.4	5.4	5.6	5.6	5.5	5.4	0.14	5.5	5.5	0.11	0.60	0.92
Juiciness[5]	5.4	5.6	5.7	5.6	5.7	5.7	0.12	5.6	5.7	0.08	0.25	0.32
Texture[6]	4.3	4.1	4.0	4.1	3.9	3.9	0.10	4.1	4.0	0.07	0.02	0.81
Off-flavor[7]	1.3	1.2	1.2	1.4	1.4	1.4	0.07	1.3	1.3	0.04	0.05	0.57

[1] Ground pork from each of 48 pigs, 8 per diet (4 barrows and 4 gilts), were analyzed during 8 trained panels.
[2] Scale of 1-8: 1= extremely weak, 8 = extremely strong.
[3] Scale of 1-8: 1= none, 8 = abundant.
[4] Scale of 1-8: 1= extremely bland, 8 = extremely intense.
[5] Scale of 1-8: 1= extremely dry, 8= extremely juicy.
[6] Scale of 1-8: 1= extremely soft, 8 = extremely hard.
[7] Scale of 1-8: 1= none, 8 = abundant.