Effects on Bacon Quality of Feeding Increasing Glycerol and Dried Distillers Grains with Solubles to Finishing Pigs

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Summary

A total of 84 barrows (PIC 337 × 1050, initially 68.3 lb) were fed a corn-soybean meal-based diet with added dried distillers grains with solubles (DDGS; 0 or 20%) and increasing glycerol (0, 2.5, or 5%) to determine the effects on belly quality. Criteria that were evaluated included: belly length, thickness, firmness, and slice yield; proximate and fatty acid analyses; iodine values; and sensory characteristics. There were no ($P > 0.08$) DDGS × glycerol interactions on any criteria measured. Inclusion of 20% DDGS in the diet decreased belly firmness ($P < 0.04$), as measured by the belly flop test (fat-side down method). Twenty percent DDGS decreased ($P < 0.01$) the percentage of myristic acid, palmitic acid, palmitoleic acid, stearic acid, oleic acid, vaccenic acid, total saturated fatty acids, and total monounsaturated fatty acids. In contrast, 20% DDGS increased ($P < 0.01$) the percentage of linoleic acid, α-linolenic acid, eicosadienoic acid, total polyunsaturated fatty acids, unsaturated:saturated fatty acid ratios, polyunsaturated:saturated fatty acid ratios, and iodine values. The inclusion of 0, 2.5, and 5% glycerol in swine diets did not affect any measured criteria in this study. In conclusion, feeding DDGS at a level of 20% decreased belly firmness and changed the fatty acid profile; however, it did not affect belly processing or sensory characteristics. Glycerol fed at 2.5 or 5.0% did not affect belly quality, fatty acid profile, or sensory characteristics of bacon.

Key words: belly quality, dried distiller grains with solubles, glycerol

Introduction

Increased demand for biofuel has increased the availability of feed coproducts from ethanol manufacturing. Dried distillers grains with solubles (DDGS), a coproduct that remains after ethanol is removed from fermented corn mash, contains high levels of nutrients in comparison to corn. With fluctuating corn prices, it is possible for producers to dramatically reduce feed costs by including it in swine diets. Dried distillers grains with solubles contains approximately 10% oil, which consists of 81% unsaturated fatty acids. Of that 81% unsaturated fatty acid content, 54% is linoleic acid (Xu et al., 2010[2]). It is known that feeding high levels of unsaturated fatty acids to pigs results in a lower

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[2] Xu, G., S.K. Baidoo, L.J. Johnston, D. Bibus, J.E. Cannon, and G.C. Shurson. 2010. Effects of feeding diets containing increasing content of corn distillers dried grains with soluble to grower-finisher pigs on growth performance, carcass composition, and pork fat quality. J. Anim. Sci. 88:1398-1410.

percentage of belly saturated fatty acids and softer bellies (Shackelford et al., 1990[3]). It has been found that belly firmness decreased linearly as dietary DDGS concentration increased. This is especially important, as bellies have become one of the most valuable pork products produced domestically. Softer bellies can result in greater variation, decreased slicing yields, a shorter shelf life, more fat separation, and more fat-smearing of bacon products (Apple et al., 2007[4]). As unsaturated fat content increases, so does softness, which can cause fat to separate from lean and be more susceptible to lipid oxidation.

At the time of this study, glycerol was an economical option to reduce feed costs in swine diets. Furthermore, it has been shown that feeding glycerol to pigs can have a beneficial effect on fat, as it lowers the concentration of unsaturated fatty acids in carcass fat (Mourot et al., 1994[5]). The objective of this study was to investigate the effect of feeding dietary glycerol and dried distillers grains with solubles on firmness, smokehouse and slice yield, bacon cooking yield, sensory characteristics of bacon, and fatty acid composition.

Procedures

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

The experiment was conducted in southwest Minnesota in a commercial swine facility. The facility had a slatted floor, and each pen was equipped with a 4-hole dry self-feeder and 1 cup waterer. The facility was a double-curtain-sided, deep-pit barn that operated on mechanical ventilation during the summer and automatic ventilation during the winter. Pigs were fed in late summer and fall of 2007.

A total of 84 barrows (PIC, 337 × 1050, initially 68.4 lb) were used in this 70-d study. Pigs were blocked by weight and randomly assigned to 1 of 6 dietary treatments with 7 pens per treatment. Animals were fed corn-soybean meal-based experimental diets. Treatments were arranged in a 2 × 3 factorial, with main effects of glycerol (0, 2.5, 5.0%) and DDGS (0 or 20%). Growth performance and backfat fatty acid profile, data from this trial were previously reported by Duttlinger et al (2008[6]).

On d-70, the two heaviest barrows were visually selected, individually tattooed, and shipped to a commercial swine harvest facility (JBS SWIFT & Company, Worthington, MN) for slaughter. After slaughter and chilling (24 h), each belly was removed

[3] Shackelford, S.D., M.F. Miller, K.D. Haydon, N.V. Lovegren, C.E. Lyon, and J.O. Reagan. 1990. Acceptability of bacon as influenced by the feeding of elevated levels of monounsaturated fats to growing-finishing swine. J. Food Sci. 55 (3): 621-624.

[4] Apple, J.K., C.V. Maxwell, J.T. Sawyer, B.R. Kutz, L.K.Rakes, M.E.Davis, Z.B. Johnson, S.N. Carr, and T.A. Armstrong. 2007. Interactive effect of ractopamine and dietary fat source on quality characteristics of fresh pork bellies. J. Anim. Sci. 85: 2682-2690.

[5] Mourot, J., A. Aumaitre, A. Mounier, P. Peiniau, and A.C. Francois. 1994. Nutritional and physiological effects of dietary glycerol in the growing pig. Consequences on fatty tissues and post mortem muscular parameters. Livestock Production Science. 38:237-244.

[6] Duttlinger et al., Swine Day 2008, Report of Progress 1001, pp. 175-185.

from the carcass according to Institutional Meat Purchasing Specification guide for a 408 fresh pork belly.

Initial belly weight (belly with skin on), length, and thickness were measured on raw bellies. Firmness was measured by centering the belly, skin-side up and skin-side down, on a stainless steel smokestick that ran perpendicular to the length of the belly. For both skin-up and skin-down orientation measurements, a measurement was taken on the dorsal and ventral sides of the belly. The measurements for firmness were measured between the 2 closest points of the flexed belly (tissue–to-tissue distance for the skin-up orientation, or skin-to-skin distance for the skin-down orientation).

Bellies were skinned and injected with a multineedle pump injector at 12% of the green weight. All bellies were weighed before and after injection, and hung on smokehouse trucks for 2 h before cooking in a smokehouse.

After chilling, cooked bellies were weighed, and the smokehouse yield of all the bellies was calculated. Bellies were placed in oxygen-impermeable vacuum-package bags (not vacuum-sealed), placed in coolers, and transferred to Jennings Premium Meats (JPM) in New Franklin, Mo., for further processing. At JPM, the cured and smoked slab bellies were pressed with a bacon press and sliced with a bacon slicer to a width of 4 mm.

Bacon slice yield was calculated by weighing the sliced bacon slab, removing the less valuable slices, then weighing the remaining #1 slices [(belly weight - (weight of #2 and #3 slices)/belly weight) × 100]. To meet the requirements for # 1 slices, the bacon strips had to have the M. *cutaneous trunci* extending more than 50% of the width of the bacon slice and slice thickness no less than 1.9 cm.

Fat samples were collected from each belly and frozen until analysis could be completed. Fatty acid results are reported as a percentage of total fatty acids in each belly sample. Iodine values, which represent the softness of the belly, were calculated by using the following equation (AOCS, 1998): C16:1(0.95) + C18:1(0.86) + C18:2(1.732) + C18:3 (2.616) + C20:1 (0.785) + C22:1(0.723). After slice-yield measurements were taken, every 10th slice, beginning from the caudal end, was collected for proximate analysis. All bacon slices were cut into small pieces, mixed into a composite sample, frozen in liquid nitrogen, pulverized in a blender, and then analyzed for protein (AOAC 990.03), moisture, fat (AOAC PVM-1:2003) and ash content (AOAC 942.05) at the K-State Analytical Laboratory. Samples for fatty acid analysis were taken from the same composite. Fatty acid results are reported as a percentage of total fatty acids in each belly sample.

Bacon slices used for sensory evaluation were removed from the belly at a point one-third the length of the belly from the cranial end. Bacon was placed on cooking racks in a Blodgett dual-air-flow oven set at 348.8°F. Slices were cooked for 5 min on each side. After cooking, slices were blotted with paper towels to remove excess grease. Bacon samples were cut into subslices and the end portions were discarded, resulting in more uniform slices. Before sensory panels began, all panelists participated in orientation sessions designed to acquaint them with the scale used for each trait. At least 8 panelists were used for each sensory evaluation session. Panelists were placed in individual booths and were required to consume a piece of apple, a piece of cracker, and water between each bacon sample to cleanse their palates. The panelists scored brittleness, bacon flavor intensity, saltiness, and off-flavors using an 8-point scale: Brittleness: 1 = extremely soft, 2 = very soft, 3 = moderately soft, 4 = slightly soft, 5 = slightly crisp, 6 = moderately crisp, 7 = very crisp, 8 = extremely crisp. Bacon flavor intensity: 1 = extremely bland, 2 = very bland, 3 = moderately bland, 4 = slightly bland, 5 = slightly intense, 6 = moderately intense, 7 = very intense, 8 =extremely intense. Saltiness: 1 = extremely un-salty, 2 = very un-salty, 3 = moderately un-salty, 4 = slightly un-salty, 5 = slightly salty, 6 = moderately salty, 7 = very salty, 8 = extremely salty. Off-flavor: 1 = extremely intense, 2 = very intense, 3 = moderately intense, 4 = slightly intense, 5 = slight, 6 = traces, 7 = practically none, 8 = none.

Ten additional bacon slices were removed from the belly at a point one-third the length of the belly from the cranial end. Of the 10 slices collected from each belly, six bacon slices were selected randomly and cooked using the same procedures described for sensory analysis. Pre- and post-cook weights were recorded, and cooking yield was calculated as [(cooked weight/raw weight) x100].

Data were analyzed by using the PROC GLM and PROC CORR procedures of SAS 9.1.3 (SAS Institute, Inc., Cary NC). Each pen (2 pigs per pen) selected for this experiment was an experimental unit. DDGS × glycerol interactions, DDGS main effects, and glycerol main effects were separated when f-tests were significant at a level of $P < 0.05$.

Results and Discussion

There were no DDGS × glycerol interactions ($P > 0.81$) observed for any criteria tested. There was no effect ($P > 0.22$) of DDGS on belly length, belly thickness, belly skin-on weight, or belly skin-off weight (Table 1). However, the inclusion of 20% DDGS decreased ($P = 0.04$) belly firmness by the belly flop skin-side down measurement and tended to reduce ($P = 0.07$) belly firmness with the belly flop skin-side up method. A decrease in belly firmness is expected with increased unsaturated fat. It was observed that including 20% DDGS in the diet decreased fat saturation, thereby reinforcing the observance of decreased belly firmness.

The inclusion of 20% DDGS to the diet tended to increase ($P = 0.06$) pump percentage, but did not affect ($P > 0.16$) the injected weight, belly cooked weight, belly smokehouse yield, #1 type bacon slice-yield weight, #1 type bacon slice yield, or bacon cooking yields (Table 2). Adding DDGS to the diet will cause belly fat to become more unsaturated. As a result, belly fat containing more unsaturated fatty acids will be softer. Therefore injection pressure might cause more brine to be injected and retained in the belly because the fat is more pliable.

The addition of 20% DDGS to the diet resulted in a trend ($P = 0.07$) toward increased moisture content (Table 3). However, there were no changes to protein, fat, or ash content ($P > 0.16$). It is possible that the inclusion of DDGS will affect fat content. It is generally known that protein and ash are relatively constant in meat; however, moisture and fat content are relatively mobile, in that an increase in moisture content will cause a decrease in fat content.

Dietary addition of DDGS at 20% decreased ($P < 0.01$) myristic acid, palmitic acid, palmitoleic acid, stearic acid, oleic acid, vaccenic acid, and total SFAs (Table 4). Inclusion of DDGS at 20% increased ($P < 0.01$) linoleic acid, α-linolenic acid, eicosadienoic acid, total MUFAs, unsaturated to saturated fatty acid ratios, polyunsaturated: saturated fatty acid ratios, and iodine values. As DDGS contains 10% oil, with 81% of that oil comprising unsaturated fatty acids, the fat that will be deposited in belly fat will be more unsaturated. Furthermore, the fatty acid profile of the diet will change the triglyceride composition that is stored in adipocytes. During low energy intake, the rate of lipolysis increases, freeing fatty acids to be oxidized. The opposite is true during high energy-intake periods, as unneeded energy is stored as triglycerides. High-fat diets will inhibit fatty acid synthesis in nonruminants, essentially shutting down or limiting de novo fat synthesis. Therefore, pigs will deposit the unsaturated fat being consumed through the diet in lieu of saturated fatty acids. As a result, the total saturated fatty acid content will decrease. In contrast, unsaturated fatty acid and polyunsaturated fatty acid content would increase, thereby increasing iodine values.

The addition of 20% DDGS to swine diets did not have any effects on bacon brittleness ($P = 0.62$), bacon flavor intensity ($P = 0.24$), saltiness ($P = 0.66$), or off-flavor ($P = 0.10$; Table 5). In theory, a higher unsaturated fat level would leave bacon samples more susceptible to lipid oxidation and result in more off-flavors. However, this was not the case in this study.

Increasing dietary glycerol (not shown in tables) showed no significant effects ($P > 0.13$) on fresh belly characteristics, belly processing characteristics, proximate analysis, fatty acid composition, or sensory characteristics. Though glycerol provides a substrate for de novo fatty acid synthesis, it is likely that glycerol showed no effects on any measurements because the fat in the diet was provided from DDGS, resulting in little de novo fat synthesis. As the de novo fatty acid synthesis in pigs is limited when a fat source is added into the diet, it can be expected that glycerol will not be used as a substrate for fatty acid synthesis. Therefore, glycerol will not affect fat saturation or flavor.

In summary, feeding pigs 20% DDGS decreased belly firmness and changed the fatty acid profile but did not affect any other belly processing or sensory characteristics. Glycerol fed at 2.5 or 5% in swine diets did not affect any belly processing characteristics, belly fatty acid composition, or sensory panelist's assessment of bacon characteristics. Therefore, feeding 20% DDGS and glycerol at 0, 2.5, and 5% showed no negative or beneficial effects on bacon quality.

Table 1. Effects of feeding dried distillers grains with solubles (DDGS) on fresh belly characteristics

	DDGS, %			
Belly Characteristics[a]	None	20	SE	P-value
Belly length, in	27.32	27.02	0.44	0.22
Belly thickness, in	1.21	1.22	0.04	0.68
Flop skin down, in	7.36	6.78	0.50	0.04
Flop skin up, in	6.34	5.95	0.37	0.07
Skin-on belly weight, lb	17.50	17.39	0.25	0.76
Skin-off belly weight, lb	14.66	14.35	0.25	0.37

[a] Values represent the mean of 42 observations.

Table 2. Effects of feeding dried distillers grains with solubles (DDGS) on belly processing characteristics

	DDGS, %			
Processing Characteristics[a]	None	20	SE	P-value
Pump %	10.35	10.79	0.16	0.06
Injected weight, lb	16.18	15.90	0.28	0.48
Belly cooked weight, lb	14.70	14.44	0.26	0.48
Smokehouse yield, %	100.15	100.50	0.22	0.26
Slice yield, lb	10.56	10.14	0.22	0.18
#1 Bacon slice yield,%	71.78	70.33	0.72	0.16
Bacon cooking yields, %	33.30	33.60	0.75	0.78

[a] Values represent the mean of 42 observations.

Table 3. Effects of feeding dried distillers grains with solubles (DDGS) on proximate analysis of bacon slices

	DDGS, %			
Composition[a]	None	20	SE	P-value
Moisture, %	40.68	42.78	0.78	0.07
Protein, %	13.12	13.53	0.30	0.33
Fat, %	43.81	41.54	1.12	0.16
Ash, %	2.56	2.18	0.33	0.42

[a] Values represent the mean of 42 observations.

Table 4. Effect of feeding dried distillers grains with solubles on belly fatty acid composition

	DDGS, %			
Item[ab]	None	20	SE	P-value
Myristic acid (14:0),%	1.47	1.36	0.01	0.01
Palmitic acid (16:0), %	24.20	22.66	0.01	0.01
Palmitoleic acid (16:1),%	2.68	2.29	0.01	0.01
Margaric acid (17:0),%	0.47	0.46	0.01	0.68
Stearic acid (18:0), %	11.71	10.87	0.01	0.01
Oleic acid (18:1c9),%	39.88	38.34	0.01	0.01
Vaccenic acid (18:1n7),%	3.38	3.03	0.01	0.01
Linoleic acid (18:2n6),%	12.28	16.92	0.01	0.01
α- Linolenic acid (18:3n3),%	0.54	0.60	0.01	0.01
Arachidic acid (20:0), %	0.22	0.20	0.01	0.06
Eicosadienoic acid (20:2),%	0.64	0.80	0.01	0.01
Arachidonic acid (20:4n6),%	0.09	0.09	0.01	0.09
Other fatty acids, %	2.40	2.34	0.01	0.15
Total SFA, %[1]	38.42	35.81	0.01	0.01
Total MUFA,%[2]	47.02	44.57	0.01	0.01
Total PUFA, %[3]	13.06	17.94	0.01	0.01
Total TFA, %[4]	0.50	0.49	0.01	0.90
UFA:SFA ratio[5]	1.57	1.75	0.02	0.01
PUFA:SFA ratio[6]	0.34	0.50	0.01	0.01
Iodine value, g/100g[7]	63.66	69.88	0.01	0.01

[1] Total saturated fatty acids = {[C8:0] + [C10:0] + [C12:0] + [C14:0] + [C16:0] + [C17:0] + [C18:0] + [C20:0] + [C22:0] + [C24:0]} where the brackets indicate concentration.

[2] Total monounsaturated fatty acids = {[C14:1] + [C16:1] + [C18:1c9] + [C18:1n7] + [C20:1] + [C24:1]} where the brackets indicate concentration.

[3] Total polyunsaturated fatty acids = {[C18:2n6] + [C18:3n3] + [C18:3n6] [C20:2] + [C20:4n6]}where the brackets indicate concentration.

[4] Total trans fatty acids = {[C18:1t] + [C18:2t] + [C18:3t]} where the brackets indicate concentration.

[5] UFA:SFA ratio = [Total MUFA + Total PUFA]/Total SFA.

[6] PUFA:SFA = Total PUFA/ Total SFA.

[7] Calculated as IV = [C16:1 x 0.95 + [C18:1] x 0.86 + [C18:2] x 1.732 + [C18:3] x 2.616 + [C20:1] x 0.785 + [C22:1] x 0.723 where the brackets indicate concentration (AOCS, 1998).

[a] Values represent the mean of 42 observations.

[b] Percentage of total fatty acid content

Table 5. Effect of feeding dried distillers grains with solubles on bacon sensory characteristics

	DDGS, %			
Sensory characteristic[a]	None	20	SE	P-value
Brittleness[1]	5.17	5.28	0.15	0.62
Bacon flavor intensity[2]	5.87	5.67	0.12	0.24
Saltiness[3]	5.7	5.73	0.06	0.66
Off-flavor[4]	7.77	7.54	0.09	0.10

[1] Brittleness: 1 = extremely soft, 2 = very soft, 3 = moderately soft, 4 = slightly soft, 5 = slightly crisp, 6 = moderately crisp, 7 = very crisp, 8 = extremely crisp.

[2] Bacon flavor intensity: 1 = extremely bland, 2 = very bland, 3 = moderately bland, 4 = slightly bland, 5 = slightly intense, 6 = moderately intense, 7 = very intense, and 8 = extremely intense

[3] Saltiness: 1 = extremely un-salty, 2 = very un-salty, 3 = moderately un-salty, 4 = slightly un-salty, 5 = slightly salty, 6 = moderately salty, 7 = very salty, 8 = extremely salty.

[4] Off-flavor: 1 = extremely intense, 2 = very intense, 3 = moderately intense, 4 = slightly intense, 5 = slight, 6 = traces, 7 = practically none, 8 = none.

[a] Values represent the mean of 42 observations.