Effects of feeding modified tall oil and supplemental potassium and magnesium on growth performance, carcass characteristics, and meat quality of growing-finishing pigs

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O'Quinn, P. R., Nelssen, J. L., Unruh, J. A., Goodband, R. D., Woodworth, J. C. and Tokach, M. D. 2000. **Effects of feeding modified tall oil and supplemental potassium and magnesium on growth performance, carcass characteristics, and meat quality of growing-finishing pigs.** Can. J. Anim. Sci. **80**: 443–449. Eighty crossbred gilts (initially 45.9 kg) were allotted randomly to one of four dietary treatments by weight and ancestry. The trial was arranged as a 2×2 factorial with two levels of modified tall oil (MTO) (0 or 0.50%) and added K_2SO_4-$2MgSO_4$ (0 or 2%), equating to daily K and Mg intakes of 10.84 and 7.75 g, respectively. The corn-soybean meal diets were fed in two phases [45.9 to 76.2 and 76.2 to 118.1 kg body weight (BW)], and supplemental K/Mg was added in place of corn for the final 7 d preslaughter (starting at 114.1 kg BW). Dietary treatment did not affect ($P > 0.10$) average daily gain (ADG), average daily feed intake (ADFI), or gain to feed ratio (G/F). Feeding MTO decreased average backfat ($P = 0.05$) and increased intramuscular marbling ($P = 0.04$). Modified tall oil increased ($P = 0.02$) percentage lean, and K/Mg supplementation lowered ($P = 0.04$) longissimus muscle glycogen content. Dietary treatment did not affect ($P > 0.10$) other carcass characteristics or measures of meat quality. Feeding MTO increased plasma glucose ($P = 0.05$) and decreased ($P = 0.10$) base excess in the extracellular fluid. Feeding K/Mg decreased ($P < 0.10$) plasma pH, BUN, and base excess in the whole-blood and extracellular fluid and increased ($P < 0.10$) ionized Mg^{++} and lactate. These results support earlier research identifying MTO as a carcass modifier and contributor to meat composition and quality. Potassium and Mg supplementation altered whole-blood profiles and longissimus muscle glycogen content in a manner expected to improve pork quality, although not observed.

Key words: Swine, modified tall oil, potassium, magnesium, meat quality

O'Quinn, P. R., Nelssen, J. L., Unruh, J. A., Goodbrand, R. D. Woodworth, J. C. et Tokach, M. D. 2000. **Effets de l'utilisation du tallol modifié et d'un supplément de magnésium sur les performances de croissance, les caractères de carcasse et la qualité de la viande de porcs en croissance- finition**. Can. J. Anim. Sci. **80**: 443–449. Quatre-vingts cochettes croisées (poids de départ 45,9 kg) étaient affectées au hasard à l'un de quatre régimes alimentaires par catégorie de poids et par ascendance. L'essai était disposé en factoriel 2×2, comportant deux niveaux de tallol modifié (TOM), 0 ou 0,50 %, et deux doses de Mg, 0 ou 2 %, correspondant à une consommation journalière de 7,75 g de Mg. Les régimes à base de maïs et de soja étaient administrés en deux phases, soit du poids corporel de 45,9 à 76,2 et de 76,2 à 118,1 kg et le Mg (0 ou 2%) était administré au lieu de maïs dans les 7 jours précédant l'abattage (à partir du PC de 114,1 kg). Les traitements alimentaires étaient sans effet ($P > 0,10$) sur le GMQ, sur l'ingéré quotidien moyen ou sur l'efficacité alimentaire. La distribution du TOM causait la diminution de l'épaisseur moyenne du lard dorsal ($P = 0,05$) et l'accroissement du persillé (intramusculaire) ($P = 0,04$). Il provoquait en outre l'accroissement ($P = 0,02$) de la proportion de maigre, tandis que l'apport de Mg se répercutait par une chute de la teneur en glycogène du longissimus. Il n'y avait pas d'effets significatifs ($P > 0,10$) sur les autres caractères de croissance ni sur les paramètres qualitatifs de la viande. Le TOM causait une hausse de la teneur en glucose du plasma et une baisse ($P = 0,10$) de l'excédent de bases dans le liquide extracellulaire. Enfin, le complément de Mg abaissait ($P < 0,10$) le pH plasmatique, l'azote uréique du sang et l'excédent de base, dans le sang entier et dans le liquide extracellulaire et relevait ($P < 0,10$) la teneur en Mg^{++} et en lactate de la viande. Ces observations viennent conforter les recherches antérieures qui établissaient l'utilité du TOM comme modificateur des caractères de carcasse et comme améliorant de la composition et de la qualité de la viande. La modification des profils sanguins et de la teneur en glycogène du muscle longissimus apportée par la complémentation magnésienne devait se traduire par une amélioration de la qualité de la viande mais cet effet n'a pas pu être clairement établi.

Mots clés: Porcs, tallol modifié, TOM, magnésium, qualité de la viande

One of the primary goals of swine production and nutrition is to produce lean pork, but now improving meat quality also is emphasized. Studies have shown that compounds such as porcine somatotropin and β-adrenergic agonists increase percentage lean in pigs. However, these agents typically decrease marbling and increase shear force (Goodband et al. 1993). Tall oil is the nonaqueous layer of

Abbreviations: **ADFI**, average daily feed intake; **ADG**, average daily gain; **CLA**, conjugated linoleic acids; **G/F**, gain to feed ratio; **MTO**, modified tall oil; **PSE**, pale, soft, and exudative

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Table 1. Percentage composition of diets (as-fed basis)

Ingredient (%)	IFN[z]	Grower[y]	Finisher[x]	7-d preslaughter[w]
Corn	4-02-935	69.24	78.58	76.58
Soybean meal (46.5% CP)	5-04-612	27.47	18.39	18.39
Limestone	6-02-632	1.06	0.89	0.89
Monocalcium phosphate	6-26-334	0.85	0.76	0.76
Soybean oil[v]	4-07-983	0.50	0.50	0.50
Salt	6-04-152	0.35	0.35	0.35
Vitamin premix[u]	–	0.25	0.25	0.25
Trace mineral premix[t]	–	0.15	0.15	0.15
Antibiotic[s]	–	0.13	0.13	0.13
K_2SO_4-2$MgSO_4$[r]	6-06-177	–	–	2.00
Analyzed Mg, %[q]		0.25	0.23	0.43
Analyzed CP, %[q]		18.36	14.96	14.84

[z]International Feed No. (NRC 1998).
[y]Grower diets were fed from 45.9 to 76.2 kg BW and were formulated to contain 1.00% lysine, 0.65% Ca, and 0.55% P.
[x]Finisher diets were fed from 76.2 to 118.1 kg BW and were formulated to contain 0.75% lysine, 0.55% Ca, and 0.50% P.
[w]Diets were fed for 7 d prior to slaughter (114.1 to 118.1 kg BW) and were formulated to contain 0.75% lysine, 0.55% Ca, and 0.50% P.
[v]Modified tall oil was substituted for an equal weight of soybean oil to give the experimental treatments.
[u]Provided per kg of complete diet: vitamin A, 8818 IU; vitamin D_3, 1322 IU; vitamin E, 35.27 IU; menadione (menadione dimethylpyrimidinol bisulphite), 3.52 mg; vitamin B_{12}, 0.03 mg; riboflavin, 7.94 mg; pantothenic acid, 26.46 mg; and niacin, 44.10 mg.
[t]Provided per kg of complete diet: Zn (from zinc oxide), 165.3 mg; Fe (from ferrous sulfate), 165.3 mg; Mn (from manganese oxide), 39.7 mg; Cu (from copper sulfate), 16.5 mg; I (from calcium iodate), 0.3 mg; and Se (from sodium selenite), 0.3 mg.
[s]Provided 110 mg kg^{-1} tylosin.
[r]Potassium magnesium sulfate was substituted on an equal weight basis (2% of total diet) with corn during the last 7 d of the finishing period to achieve the additional dietary treatments.
[q]Values represent the averages of diets within each growth period.

rosin acids and fatty acids produced during the kraft (sulfate) paper process. Modified tall oil contains high levels of CLA (about 70%) and results from further processing of the fatty acid portion of tall oil (O'Quinn et al. 2000). The use of MTO as a source of CLA may minimize the reduction in meat quality typically seen when improvements in carcass leanness are achieved. A recent study showed that CLA increased percentage lean in swine (Dugan et al. 1997) and increased intramuscular marbling (Dugan et al. 1999). O'Quinn et al. (2000) demonstrated that feeding MTO increased carcass leanness, and Waylan et al. (1999) demonstrated that feeding MTO in conjunction with elevated levels of vitamin E improved meat quality by extending display color stability and reducing oxidative deterioration.

Magnesium is an essential cofactor for numerous enzymatic reactions (Wacker 1969), and Mg supplementation is a method of reducing the effects of stress-induced metabolic events (Golf et al. 1984), thereby providing the potential to improve some measures of meat quality in swine. Recently, short-term Mg aspartate supplementation was shown to decrease drip loss, lactic acid, and L* values and increase pH (D'Souza et al. 1998) in finishing pigs. It is reasonable to expect that the inclusion of high levels of K_2SO_4-2$MgSO_4$ would improve meat quality through alterations in whole-blood profiles. Schaefer et al. (1993) suggested that pigs demonstrating pale, soft, and exudative (PSE) meat also exhibit high venous levels of CO_2, bicarbonate, and base excess, which could be treated with Na, K, or Mg salts. Although KCl did lower PCO_2 levels in their study, corresponding meat quality improvements from KCl supplementation were negligible. Kauffman et al. (1998) demonstrated that a postmortem injection of sodium bicarbonate in the longissimus muscle may reduce symptoms of PSE pork. For these reasons, K/Mg was chosen as the supplement instead of Mg aspartate.

Therefore, the current trial was conducted to evaluate the effects of feeding MTO and supplemental K/Mg (when matched with Mg aspartate for availability) on growth performance, carcass characteristics, and meat quality measures of growing-finishing pigs.

MATERIALS AND METHODS

Animals and Diets

Pigs used in this experiment were terminal offspring of PIC L326 or 327 boars × C22 sows (PIC, Franklin, KY). Experimental procedures were approved by the Kansas State University Institutional Animal Care and Use Committee (Protocol No. 1593).

Eighty crossbred gilts (initially 45.9 kg ± 2.5 SD) were used. Pigs were blocked on the basis of initial weight and ancestry in a randomized complete block design and allotted randomly to one of four dietary treatments arranged as a 2 × 2 factorial with 10 replicate pens per treatment. However, two of the four dietary treatments (K/Mg supplementation) were implemented near the end of the experimental period, so there were 20 pens per dietary treatment until then.

Diets were formulated to meet or exceed nutrient requirements for pigs of this weight as set forth by the National Research Council (NRC 1998) for pigs with high lean-gain potential, and diets were fed in meal form in two phases (45.9 to 76.2 and 76.2 to 118.1 kg BW; Table 1). The preselected pens of pigs were changed to a K/Mg-supplemented

diet 7 d preslaughter (114.1 kg ± 6.4 SD). Modified tall oil was substituted on an equal weight basis for soybean oil, and potassium magnesium sulfate (K_2SO_4-$2MgSO_4$; CAS No. 14977-37-8) was substituted on an equal weight basis (2% of the total diet) with ground corn to achieve the additional dietary treatments. Diets were analyzed for CP (Association of Official Analytical Chemists 1995) and Mg (Hansen and Freier 1967). Analysis of the K_2SO_4-$2MgSO_4$ showed that it contained 17.9% K, 12.8% Mg, and 24.1% S. Diets were not analyzed for fatty acids; however, the MTO was analyzed prior to initiation of the experiment using similar procedures as described by O'Quinn et al. (2000). The MTO was found to contain 1.04% saturated fatty acids, 17.32% octadecenoic acid, 6.90% linoleic acid, 68.30% CLA, and 6.44% unidentified lipids. The CLA fraction was also separated into its cis (*c*) and trans (*t*) isomeric components. This CLA fraction was composed of 31.74% *c*9, *c*11; 28.26% *c*9, *t*11; 14.71% *t*10, *c*12; 12.21% *t*9, *t*11; 7.98% unidentified *c*,*c* isomers; and 5.10% unidentified *t*,*t* isomers.

The level of supplemental Mg chosen for this experiment was based on the data of D'Souza et al. (1998) using Mg aspartate and on an initial pilot study conducted at Kansas State University (data not shown) using three levels (1, 2, or 4%) of K_2SO_4-$2MgSO_4$. Because serum Mg level has been used widely as a criterion of Mg bioavailability (Henry and Benz 1995), the goal of the pilot study was to match the increase (6.11%) in Mg levels observed by D'Souza et al. (1998). This provided a means of accounting for the differences in relative bioavailabilities of Mg aspartate used by those authors and of K_2SO_4-$2MgSO_4$ used in the pilot study. Feeding 2% K_2SO_4-$2MgSO_4$ in the pilot study elicited a 9.61% increase in serum Mg without reducing ADFI. Adding 1% K_2SO_4-$2MgSO_4$ did not significantly ($P > 0.10$) increase serum Mg levels, and 4% K_2SO_4-$2MgSO_4$ significantly ($P < 0.10$) reduced ADFI. Based on these findings, the feeding of 2% K_2SO_4-$2MgSO_4$ in the current study equated to average K and Mg intakes of 10.84 and 7.75 g d^{-1}, respectively, for the last 7 d preslaughter.

Handling and Response Criteria

Pigs were housed in an environmentally controlled finishing barn with two pigs in each 1.33 m × 1.33 m totally slatted-floored pen. Pigs were allowed ad libitum access to feed and water through one single-hole self-feeder and a nipple waterer, respectively. Pigs were weighed every 14 d and at the beginning and end of the K/Mg supplementation period in order to determine ADG, ADFI, and G/F. Serum samples were obtained by vena cava puncture from each pig at the beginning of the K/Mg supplementation period and again 5 d later for determination of initial and final Mg levels, respectively (Hansen and Freier 1967). Whole-blood samples also were obtained on the 5th d of K/Mg supplementation for the determination of blood gas and metabolic profiles (National Committee for Clinical Laboratory Standards 1982). Feed was not withheld from pigs prior to blood sampling. Blood sampling was conducted 2 d before slaughter so that the stress of bleeding would not interfere with or influence measures of meat quality. Blood gas and metabolic profiles were determined within 25 min of sampling using a Stat Profile M Blood Gas and Electrolyte Analyzer (Nova Biomedical Corp., Waltham, MA), and serum samples for Mg analyses were stored frozen until analyzed. Anion gap was defined as $(Na^+ + K^+) - (Cl^- + HCO_3^-)$, or cations – anions. Base excess was defined as the amount of titratable base.

One pig (closest to the average weight of all pigs) per pen was slaughtered after 7 d of receiving supplemental K/Mg (average slaughter weight of 118.1 kg ± 5.4 SD). Twelve hours prior to slaughter, pigs were transported approximately 3 km to the Kansas State University abattoir where they were held without feed in pens of 10 pigs each. Pigs were electrically stunned (500 V for 4–6 s) prior to exsanguation. Thirty minutes after exsanguation, a 1.91-cm core sample, taken at the last rib 2.54 cm from the right side of the midline, was removed from the longissimus muscle of each carcass, immediately dipped in liquid nitrogen, placed on dry ice, then stored at –70°C until analyzed for glycogen (Dreiling et al. 1987). Lactic acid content of the longissimus muscle also was determined using a commercially available diagnostic kit (Sigma Chemical, St. Louis, MO). Standard carcass measurements – visual analyses of the longissimus muscle for coloring, marbling, and firmness (National Pork Producers Council 1991), drip loss [modified from Kauffman et al. (1986)], and Minolta color spectrophotometry [*L**, *a**, and *b** (Commission Internationale de l'Eclairage 1976)] – were obtained for each pig at 24 h postmortem (drip loss = 48 h postmortem). Color spectrophotometry measurements (three surface readings per loin) were determined with a Minolta Chroma Meter Model CR-200 using illuminant C (Minolta Co., Ltd., Osaka, Japan). Visual and instrumental evaluations of the longissimus muscle were determined following a 30-min bloom.

Statistical Analysis

Data were analyzed as a randomized complete block. Pen was the experimental unit for the growth performance data, and serum and blood gas measurements and individual pig (one pig/pen) was the experimental unit for the carcass characteristics and meat quality measurements. Data, including the last 7 d of the finishing period, were analyzed in a 2 × 2 factorial arrangement with main effects of MTO (0 or 0.50% of the diet) or supplemental K/Mg (0 or 10.84 g of K d^{-1} and 7.75 g of Mg d^{-1} for 7 d preslaughter) using GLM procedures (SAS Institute, Inc. 1985). The statistical model included main effects and interactions of the main effects. Hot carcass weight was used as a covariate in the statistical model for quantitative carcass measurements. Interactions of MTO and K/Mg were considered significant at the 0.05 probability level. When a significant interaction was observed (dressing percentage), means were separated using the Least Significant Difference procedure (SAS Institute, Inc. 1985).

RESULTS

Growth Performance

Modified tall oil did not affect ($P > 0.15$) ADG, ADFI, or G/F during the growth trial (Table 2). The addition of sup-

Table 2. Growth performance of gilts fed MTO[z]

	MTO (%)			
Item	0	0.50	SEM	Probability
45.9 to 118.1 kg BW				
ADG (kg)	1.00	0.97	0.012	0.24
ADFI (kg)	2.84	2.76	0.039	0.16
G/F	0.35	0.35	0.031	0.63

[z]Values are means for 20 replicate pens per treatment and two pigs per pen.

plemental K/Mg to these diets did not affect ($P > 0.10$) ADG, ADFI, or G/F for the 7 d preslaughter supplementation period; thus, combined data for growth performance are reported herein. Although the short-term, large dose of K/Mg did not affect ADFI, a slight laxative effect was observed, which was probably related to the chemical composition and properties of K_2SO_4-$2MgSO_4$.

Carcass Characteristics and Meat Quality

Feeding MTO reduced ($P \leq 0.05$) 1st and 10th rib and average backfat (Table 3). Interactions of MTO and K/Mg were observed for dressing percentage ($P = 0.05$). Pigs fed diets containing supplemental K/Mg and MTO had higher ($P < 0.10$) dressing percentage than pigs fed diets containing just MTO. Modified tall oil increased ($P = 0.04$) intramuscular marbling. Supplemental K/Mg decreased ($P = 0.04$) longissimus muscle glycogen content but did not affect lactic acid concentration. The short-term, large dose of K/Mg increased ($P = 0.0001$) serum Mg levels by about 7%, which closely matched the increase in Mg observed by D'Souza et al. (1998) from feeding Mg aspartate. Other longissimus muscle characteristics, including all color measurements and drip loss percentage, were not affected ($P > 0.10$) by dietary treatment.

Blood Gas and Metabolic Profiles

No interactions of MTO and K/Mg were observed ($P > 0.15$) for any of the measured or calculated blood gas and metabolic profiles (Table 4). Feeding MTO increased ($P = 0.05$) glucose and anion gap and tended to decrease ($P = 0.10$) base excess in the extracellular fluid. The effects of the K/Mg supplementation were readily apparent in the blood gas and metabolic profiles. Feeding K/Mg tended to decrease ($P < 0.10$) pH, BUN, and base excess in both the whole-blood and extracellular fluid. Feeding K/Mg tended to increase ($P < 0.10$) whole-blood concentrations of K^+, ionized Mg^{++}, lactate, and anion gap.

Table 3. Carcass characteristics of gilts fed MTO, supplemental potassium and magnesium (K_2SO_4-$2MgSO_4$), or both[z,y]

	0 MTO		0.50% MTO					
	K_2SO_4-$2MgSO_4$		K_2SO_4-$2MgSO_4$			Probability		
Item	0%	2.0%	0%	2.0%	SEM	MTO × Mg	MTO	Mg
Final BW (kg)	120.4	117.3	117.5	117.3	1.251	0.26	0.24	0.20
Shrink loss (%)	1.30	1.16	0.91	1.10	0.268	0.58	0.45	0.94
Backfat, cm								
Tenth rib	1.88	2.16	1.78	1.70	0.107	0.12	0.02	0.34
Average[x]	2.59	2.64	2.54	2.34	0.080	0.15	0.05	0.35
Longissimus muscle area(cm^2)	43.42	42.90	43.16	46.58	0.550	0.20	0.17	0.29
Lean percentage[w]	54.03	52.90	54.53	55.84	0.720	0.10	0.02	0.90
Dressing percentage	74.99*a*	74.76*ab*	73.71*b*	75.49*a*	0.473	0.05	0.66	0.10
Visual color[v]	2.60	2.55	2.55	2.70	0.175	0.55	0.82	0.78
Marbling[v]	1.95	2.25	2.45	2.45	0.159	0.37	0.04	0.36
Firmness[v]	2.55	2.55	2.80	2.75	0.221	0.92	0.33	0.91
*L**[u]	53.73	53.50	53.59	54.77	1.043	0.53	0.54	0.64
*a**[u]	12.71	14.53	12.99	12.68	0.778	0.19	0.31	0.34
*b**[u]	8.59	9.76	8.55	8.61	0.676	0.41	0.41	0.37
*a**/b*[u]	1.49	1.53	1.55	1.49	0.048	0.33	0.96	0.78
Drip loss, %	5.64	6.20	5.79	6.34	0.690	0.99	0.84	0.44
Carcass length (cm)	82.55	83.01	83.01	83.64	0.690	0.95	0.37	0.42
Muscle metabolites								
Glycogen, (mg g^{-1})	4.77	4.13	4.85	3.72	0.409	0.55	0.69	0.04
Lactic acid (mg g^{-1})	4.12	4.00	3.90	3.74	0.270	0.94	0.38	0.59
Serum Mg (initial)[t]	20.59	20.47	20.37	20.84	0.270	0.28	0.79	0.53
Serum Mg (final)[t]	21.27	22.37	20.85	22.91	0.264	0.53	0.36	0.0001

[z]Values represent 10 replicate pens per treatment and one pig per pen.
[y]Hot carcass weight was used as a covariate in the statistical analysis for quantitative carcass measurements.
[x]Average backfat is the average of the first and last rib and last lumbar fat depths.
[w]Lean percentage was derived from National Pork Producers Council (NPPC 1991) equations with 5% fat in the carcass.
[v]Scoring system of 1 to 5: 2 = grayish pink, traces to slight, or soft and watery;
3 = reddish pink, small to modest, or slightly firm and moist; and 4 = purplish red, moderate to slightly abundant, or firm and moderately dry for color, marbling, and firmness, respectively.
[u]Means were derived from three sample readings per loin. Measures are dark to light
(*L**), redness (*a**), yellowness (*b**), red to orange (hue angle), or vividness or intensity (saturation index).
[t]Serum values (mg L^{-1}) are means of 10 replicate pens per treatment and two pigs per pen.
a–b Means on a row with different letters differ ($P \leq 0.10$).

Table 4. Whole blood profiles of gilts fed MTO, supplemental potassium and magnesium (K_2SO_4-$2MgSO_4$), or both[z]

	0 MTO		0.50% MTO			Probability		
	K_2SO_4-$2MgSO_4$		K_2SO_4-$2MgSO_4$					
Item	0%	2.0%	0%	2.0%	SEM	MTO × Mg	MTO	Mg
pH	7.395	7.383	7.398	7.368	0.009	0.36	0.55	0.04
PCO_2 (mmHg)	56.5	57.7	55.5	58.8	1.481	0.50	0.97	0.14
PO_2 (mmHg)	44.5	49.3	47.0	42.8	3.370	0.20	0.57	0.92
Oxygen saturation (%)	75.6	76.1	75.6	70.9	2.261	0.27	0.27	0.39
Hematocrit (%)	41	41	41	41	0.829	0.83	0.70	0.55
Hemoglobin (g dL^{-1})	13.6	13.4	13.7	13.5	0.272	0.78	0.76	0.48
Na^+ (mmol L^{-1})	146	147	147	147	0.369	0.63	0.38	0.18
K^+ (mmol L^{-1})	5.0	5.1	4.9	5.1	0.094	0.73	0.63	0.10
Cl^- (mmol L^{-1})	102	103	103	103	0.255	0.69	0.35	0.98
Ionized Ca^{++} (mg dL^{-1})	5.34	5.36	5.32	5.42	0.045	0.37	0.65	0.20
Ionized Mg^{++} (mg dL^{-1})	0.88	0.98	0.92	0.97	0.038	0.51	0.81	0.07
Glucose (mg dL^{-1})	97	92	98	98	1.697	0.20	0.05	0.16
Lactate (mmol L^{-1})	2.5	2.9	2.7	3.9	0.422	0.30	0.19	0.08
BUN (mg dL^{-1})	14	11	14	11	0.784	0.99	0.95	0.01
Osmolarity, mOsm/kg	291	291	292	292	0.888	0.87	0.37	0.96
Anion gap (mmol L^{-1})	14.4	15.0	14.7	16.0	0.317	0.37	0.05	0.008
HCO_3^- (mmol L^{-1})	34.7	34.4	34.2	33.7	0.358	0.74	0.13	0.31
Oxygen content mL dL^{-1}	15.1	15.2	15.1	14.2	0.458	0.28	0.29	0.41
Total CO_2 (mmol L^{-1})	36.4	36.2	35.9	35.6	0.380	0.83	0.15	0.49
Alveolar oxygen (mmHg)	76.3	74.7	77.4	73.5	1.762	0.51	0.98	0.14
Base excess-WB(mmol L^{-1})[y]	8.4	8.0	8.2	7.1	0.349	0.41	0.11	0.04
Base excess-ECF (mmol L^{-1})[x]	9.6	9.2	9.2	8.3	0.382	0.51	0.10	0.08

[z]Values represent 10 replicate pens per treatment and one pig per pen.
[y]Base excess in the whole blood.
[x]Base excess in the extracellular fluid.

DISCUSSION

The general lack of a growth response in the current trial from feeding MTO agrees with prior data from this laboratory (O'Quinn et al. 1999c, 2000), which also did not show improvements in growth performance from feeding MTO. However, O'Quinn et al. (1999b) did report increases in ADG and ADFI in gilts fed MTO.

Changes in growth performance from feeding supplemental Mg have not been reliable indicators of relative Mg bioavailability (Henry and Benz 1995). Not surprisingly, growth performance among dietary treatment groups was similar in the current study. The majority of studies evaluating the influence of Mg sources on growth performance and carcass characteristics have included low levels of a Mg source provided for the duration of the growing-finishing phases of growth (Otten et al. 1992; Tortuero and Rioperez 1993; Lindemann et al. 1998; Apple et al. 1999). Although D'Souza et al. (1998) fed a short-term (5 d), high dose of Mg from Mg aspartate, the animals were limit fed.

The increase in percentage lean in pigs fed MTO resulted primarily from reduced backfat which, agrees with prior data for both MTO (O'Quinn et al. 2000) and CLA (Dugan et al. 1997; Thiel et al. 1998). Feeding MTO also increased intramuscular marbling in the longissimus muscle in the present study. Dugan et al. (1999) reported similar findings from including 2% CLA in the diet. Thus, the increased marbling from the addition of MTO likely could lead to increased juiciness and palatability. In mice (Belury and Kempa-Steczko 1997) and rats (O'Quinn et al. 1999a), tissue lipid enrichment by CLA and MTO, respectively, has been reported.

Potassium and Mg supplementation did not affect backfat thickness. Lindemann et al. (1998) reported no effects on backfat or longissimus muscle area in swine fed different Mg sources for the duration of the growing-finishing period. Similarly, Apple et al. (1999) demonstrated no effects of various Mg supplements on backfat in finishing lambs.

The primary focus for Mg supplementation in relation to meat quality in swine has been to counteract the stresses facing the pig immediately preslaughter, such as transportation, fighting with other pigs, and new surroundings, as well as the actual processes of stunning and exsanguation. Magnesium has been shown to decrease the typical rises in cortisol (Golf et al. 1984) and catecholamines (Otten et al. 1992) after stress. Stressful situations close to harvest in pigs are known to contribute to rapid postmortem glycogen breakdown, increased drip loss percentage, decreased pH, and less-desirable color (increased L^* and decreased a^* values). However, in the present study, K/Mg supplementation decreased postmortem glycogen levels, but did not affect any color measurements or drip loss percentage. Consistent with CLA (Dugan et al. 1999), MTO did not affect glycogen or lactic acid content of the longissimus muscle when measured at 30 min postmortem. Glycogen and lactic acid values in the present study were similar to those reported by D'Souza et al. (1998). Although feeding K/Mg reduced glycogen, lactic acid was not increased. Essen and Lindholm (1981) concluded that a high rate of postmortem glycolysis leads directly to an elevated production of lactic acid because glycogen is the primary source of lactate production; however, the rate of depletion of postmortem glycogen was not determined in the current study. The

reduction in glycogen levels from feeding K/Mg would be beneficial in improving pork color and drip loss percentage. Lower muscle glycogen content antemortem should lead to less lactic acid formation postmortem, thereby resulting in higher pH, and decreased L* values and drip loss percentage, though these improvements were not observed in the current study.

The whole-blood measurements in the current study for pH, PCO_2, and HCO_3^- are similar to those presented by Patience (1990) in an acid-base review. However, as with results of Schaefer et al. (1993), the improvements in base excess from feeding K/Mg did not correlate to improvements in meat quality. Feeding K/Mg slightly reduced whole-blood pH, but whether this was a K or a Mg response or both is unclear. The net acid load of the diet is calculated primarily by subtracting the contributions of Cl, P, and S from those of Na, K, Ca, and Mg (Patience and Chaplin 1997). Because K_2SO_4-$2MgSO_4$ contains 30.7% K plus Mg and only 24.0% S, it is reasonable to expect decreases in pH and increases in lactate from its feeding to swine. Though no responses in meat quality could be attributed clearly to the alterations in whole-blood profiles, these changes may merit further investigation.

This is the first known study to investigate the effects of MTO on whole-blood profiles. Thus, the effects of MTO on glucose, anion gap, and extracellular base excess are not readily explainable. However, these data provide a benchmark for future work. If lowering base excess is critical to improving meat quality of PSE pigs, then MTO may be beneficial from that standpoint alone.

CONCLUSIONS

These results indicate that modified tall oil reduces backfat and increases intramuscular marbling in growing-finishing swine. The use of supranutritional levels of potassium and magnesium may not be necessary under normal slaughter conditions where pigs are not subjected to other stresses. Altering whole-blood profiles by feeding either modified tall oil or potassium magnesium sulfate did not influence meat quality. Feeding modified tall oil to pigs warrants further investigation because of the improvements in carcass leanness and meat quality observed. The use of supplemental potassium and magnesium to alter whole-blood profiles and improve meat quality also deserves further attention.

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