Performance and bunk attendance of cattle fed steam-rolled or ground corn supplemented with laidlomycin and chlortetracycline or monensin and tylosin

D. J. Gibb[1], M. Streeter[2], K. S. Schwartzkopf-Genswein[1], and T. A. McAllister[1]

[1]*Agriculture and Agri-Food Canada, Lethbridge Research Centre, 5403 – 1st Avenue South, Lethbridge, Alberta, Canada T1J 4B1 (e-mail: gibbd@agr.gc.ca); and* [2]*Alpharma Inc., 1 Executive Drive, Fort Lee, NJ, 07024 USA.*
LRC contribution no. 38707022. Received 7 June 2007, accepted 5 May 2008.

Gibb, D. J., Streeter, M., Schwartzkopf-Genswein, K. S. and McAllister, T. A. 2008. **Performance and bunk attendance of cattle fed steam-rolled or gound corn supplemented with laidlomycin and chlortetracycline or monensin and tylosin**. Can. J. Anim. Sci. **88**: 499–506. British cross steer calves ($n = 240$; 332 ± 23 kg) in 16 pens were fed ground (G) or steam-rolled (SR) corn-based finishing diets medicated with 12 mg kg^{-1} laidlomycin propionate and 42.2 mg kg^{-1} chlortetracycline hydrochloride (LC) or with 30.4 mg kg^{-1} monensin sodium and 10.5 mg kg^{-1} tylosin phosphate (MT) in a 2×2 factorial experiment. Individual bunk attendance was monitored using radio frequency identification in one pen per diet. Finishing diets were fed for 125 d following a 27-d adaptation from 65 to 91% concentrate diet. In the first 56 d and overall, daily dry matter intake (DMI) was greater ($P < 0.05$) with LC than with MT (8.8 vs. 8.3 kg), but did not differ ($P = 0.97$) between G and SR diets. There was a trend ($P = 0.11$) towards greater ADG for cattle fed LC than those fed MT (1.54 vs. 1.47 kg d^{-1}), but gain:feed was similar (0.169; $P = 0.80$) between antibiotic supplements. Processing method did not ($P = 0.29$) affect rate of gain, but SR tended ($P = 0.06$) to improve gain:feed compared with G (0.171 vs. 0.165). Steers fed LC spent more ($P < 0.001$) time at the bunk than those fed MT (125 vs. 120 min d^{-1}). On G diets, cattle fed LC made fewer daily visits (9.3 vs. 9.5 visits d^{-1}; $P = 0.03$), but spent more time at the bunk (135.9 vs. 124.0 min d^{-1}; $P < 0.001$) resulting in greater duration per meal (15.4 vs. 13.7 min meal^{-1}; $P < 0.001$). These cattle also had the greatest deviation in daily duration at the bunk (37.3 vs. 33.7 min; $P < 0.001$). The prevalence of liver abscesses was 13.2% with LC and 6.5% with MT ($P = 0.09$). However, the prevalence of severely abscessed livers (2.9%) was unaffected ($P = 0.45$) by treatment. The prevalence of foot rot was greater ($P = 0.02$) for cattle fed MT (7.5%) than for cattle fed LC (0.8%). Compared with feeding MT, feeding LC may enhance ADG, possibly due to greater DMI.

Key words: Beef, chlortetracycline, corn processing, laidlomycin, monensin, tylosin

Gibb, D. J., Streeter, M., Schwartzkopf-Genswein, K. S. et McAllister, T. A. 2008. **Rendement des bovins nourris de flocons ou de farine de maïs enrichis de laidlomycine et de chlortétracycline ou de monensin et de tylosine et fréquentation des mangeoires**. Can. J. Anim. Sci. **88**: 499–506. Des bouvillons hybrides britanniques ($n = 240$; 332 ± 23 kg) répartis dans 16 enclos ont reçu une ration de finition à base de farine (G) ou de flocons (SR) de maïs à laquelle on avait ajouté 12 mg de propionate de laidlomycine et 42,2 mg de chlorhydrate de chlorotétracycline (LC) par kg ou 30,4 mg de monensin sodique et 10,5 mg de phosphate de tylosine (MT) par kg, dans le cadre d'une expérience factorielle 2×2. Les auteurs ont surveillé la fréquentation des mangeoires grâce à l'identification par radiofréquence à raison d'un enclos par ration. Les rations ont été servies pendant 125 jours après une période d'adaptation de 27 jours durant laquelle les animaux sont passés de 65 à 91% de concentré. Au cours des 56 premiers jours et globalement, l'ingestion quotidienne de matière sèche était plus élevée ($P < 0,05$) avec la ration LC qu'avec la ration MT (8,8 c. 8,3 kg), alors qu'elle était la même ($P = 0,97$) pour les traitements G et SR. Les bovins recevant la ration LC ont tendance ($P = 0,11$) à enregistrer un gain quotidien moyen plus élevé que ceux nourris avec la ration MT (1,54 c. 1,47 kg j^{-1}), mais le ratio gain:aliment était analogue (0,169; $P = 0,80$) pour les deux suppléments d'antibiotiques. La méthode de transformation n'affecte pas ($P = 0,29$) le taux de gain, mais le conditionnement SR tend ($P = 0,06$) à améliorer le ratio gain/aliment comparativement au traitement G (0,171 c. 0,165). Les bouvillons nourris avec la ration LC passent plus ($P < 0,001$) de temps à la mangeoire que ceux recevant la ration MT (125 c. 120 min par jour). Avec la farine, les bovins recevant le mélange LC se présentent moins souvent à l'auge (9,3 fois par jour; $P = 0,03$) mais ils y restent plus longtemps (135,9 c. 124,0 min. par jour; $P < 0,001$), ce qui prolonge la durée du repas (15,4 c. 13,7 min.; $P < 0,001$). Ces animaux présentent aussi la plus grande divergence en ce qui concerne le temps quotidiennement passé à la mangeoire (37,3 c. 33,7 min.; $P < 0,001$). La fréquence des abcès au foie était de 13,2% pour la

[3]*Current address: Intervet/Scheringer Plough Animal Health, 29160 Intervet Lane, P.O. Box 319, Millsboro, DE 19966.*

Abbreviations: DMI, dry matter intake; **G**, corn ground so at least 65% passed through a 1.18-mm screen; **LC**, diet contained 12 mg kg^{-1} laidlomycin propionate and 42 mg kg^{-1} chlortetracycline; **MT**, diet contained 30 mg kg^{-1} monensin sodium and 11 mg kg^{-1} tylosin phosphate; **SR**, diets in which corn was steam-rolled

ration LC et de 6,5% pour la ration MT ($P = 0{,}09$). La prévalence des foies gravement atteints (2,9%) était toutefois la même ($P = 0{,}45$) pour les deux traitements. Le piétin prévalait davantage ($P = 0{,}02$) chez les animaux nourris avec la ration MT (7,5%) que chez ceux recevant le mélange LC (0,8%). Comparativement à la ration MT, la ration LC pourrait améliorer le gain quotidien moyen, sans doute en raison d'une meilleure ingestion de la matière sèche.

Mots clés: Bœuf, chlorotétracycline, conditionnement du maïs, laidlomycine, monensin, tylosine

High-grain diets commonly fed in the feedlot industry increase digestive and metabolic disease (Galyean and Rivera 2003). Ionophores and antibiotics to control liver abscesses are the primary feed additives used in the Canadian feedlot industry to manage these challenges. Ionophores may enhance the efficiency of ruminal fermentation by shifting microbial profiles (Bergen and Bates 1984) and stabilizing ruminal pH (Nagaraja et al. 1982). The effect of ionophores on feeding behaviour may also contribute to their efficacy. Monensin reduced eating rates (Chirase et al. 1992), meal size (Gibb et al. 2001) and variation in intake (Stock et al. 1995). Oral antibiotics used to reduce liver abscesses target specific bacterial populations, such as *Fusobacterium necrophorum* and *Actinomyces pyogenes*, that enter the portal circulatory system through lesions in the ruminal epithelium. Uncontrolled, these bacteria can enter portal circulation and become isolated and encapsulated in hepatocytes to form cysts and ultimately liver abscesses (Nagaraja and Chengappa 1998). Aggressive processing of grains reduces ruminal pH (Zinn 1990) and may thereby increase digestive challenges and influence response to feed additives.

This experiment investigated the effect of feed processing and feeding laidlomycin propionate and chlortetracycline hydrochloride [Alpharma, Inc., Bridgewater, NJ (LC)] compared with monensin sodium and tylosin phosphate [Elanco Animal Health, Guelph ON (MT)] on growth, carcass traits, prevalence of liver abscesses, and feeding behaviour in feedlot steers.

MATERIALS AND METHODS

On arrival, 250 medium-framed British cross steers (332 ± 23 kg) were placed in 1 of 16 pens and fed a diet containing 20.6% barley, 72.8% silage and 6.6% supplement (DM basis). Hay was also delivered into feed bunks separately from the mixed ration for the first 10 d. Approximately 1 wk after arrival of the last group, cattle were ear tagged and received Dectomax (Pfizer Animal Health, Kirkland, QC), an eight-way clostridial vaccine (Tasvax; Intervet, Whitby, ON), and an IBR, PI_3 and *Haemophilus somnus* vaccine (Resvac 4; Pfizer Animal Health, Kirkland, QC). Steam-rolled corn replaced all of the barley before the start of the trial. Feed and water were withheld for a 24-h period prior to obtaining an initial weight. Following the initial weight, the 10 lightest and heaviest animals were removed, resulting in 240 animals which were then randomly allotted into 16 pens (15 animals per pen). Each pen was randomly assigned to receive one of the following four diets in a 2×2 factorial arrangement of treatments: (1) 30 mg kg^{-1} monensin sodium and 11 mg kg^{-1} tylosin phosphate fed with steam-rolled corn (SRMT), (2) the same as treatment 1, but the corn was ground through 6.3-mm screen using a Bliss E-1912 TF hammer mill so that at least 65% passed through a 1.18-mm sieve (GMT), (3) 12 mg kg^{-1} laidlomycin propionate and 42 mg kg^{-1} chlortetracycline hydrochloride fed with steam-rolled corn (SRLC), and (4) the same as treatment 3, but the corn was ground (GLC). Target quantities of tylosin and chlortetracycline were 90 and 350 mg head^{-1} d^{-1}, respectively. Prior to steam-rolling, corn was retained in the steam chest for an average of 10 min at 85°C. To accentuate differences in processing, roller spacing was set to ensure a coarse roll with a flake density of 0.55 kg L^{-1}, which is considerably less aggressive than typical steam-flaked corn (Zinn et al. 2002). Steers were confined in outdoor pens (14 m $\times$ 20 m), and maintained according to the guidelines of the Canadian Council on Animal Care (CCAC 1993). One pen from each treatment was equipped with the GrowSafe^{TM} system (Airdrie, AB) as previously described by Schwartzkopf-Genswein et al. (1999). This system collected individual feeding behaviour data including frequency of visits (visits d^{-1}), bunk attendance duration (min d^{-1}), daily deviation from mean duration (min), meal duration (min meal^{-1}) and meal intensity (%), calculated as the percentage of the time the animal was at bunk with its head in the bunk (assumed to be consuming feed). These data were collected on all 60 individuals [15 animals (one pen) in each of the four treatments] over the entire 152-d trial.

Medications were delivered through a supplement that was included at 10% of diet DM (Table 1). Each tonne of supplement contained either 1.02 kg Cattlyst® (110 000 mg kg^{-1} laidlomycin propionate) and 3.57 kg Aureomycin® 50 (110 000 mg kg^{-1} chlortetracycline hydrochloride), or 1.42 kg Rumensin® 200 (200 000 mg kg^{-1} monensin sodium) and 1.11 kg Tylan® 40 (88 mg kg^{-1} tylosin phosphate). Bi-weekly samples of the two supplements and the four treatment diets were assayed to confirm medication levels. The LC supplement and diets were analyzed at Alpharma Animal Health (Chicago Heights, IL) and the MT supplement and diets were analyzed at AT Laboratory (Memphis, TN). To avoid cross contamination between loads of feed, the feed wagon was completely emptied between loads.

Cattle were fed once daily between 0800 and 1000 using a Knight Little Augie feed mixer (Broadhead, WI). Cattle were fed to maintain minimal daily orts and

Table 1. Formulae, analysis, and medication levels (DM basis) of diets containing monensin and tylosin or laidlomycin and chlortetracycline

	Transition 1	Transition 2	Transition 3	Finish
Day of feeding	1–15	16–21	22–27	28–140
Ingredient				
Corn (%)	55.0	65.0	75.0	81.0
Barley silage (%)	35.0	25.0	15.0	9.0
Supplement[z] (%)	10.0	10.0	10.0	10.0
Total	100.0	100.0	100.0	100.0
Analysis				
Dry matter (%, as fed)	57.2	63.3	71.0	76.5
Protein (%)	13.9	14.0	13.8	13.7
Non-protein nitrogen (%)	2.6	2.6	2.6	2.6
NDF (%)	25.1	21.0	16.9	14.5
Calcium (%)	0.70	0.68	0.66	0.64
Phosphorus (%)	0.31	0.31	0.32	0.32
Magnesium (%)	0.40	0.32	0.32	0.31

[z]Contained either 120 mg laidlomycin and 422 mg chlortetracycline kg^{-1} of dry matter or 304 mg monensin and 105 mg tylosin kg^{-1} of dry matter. Also provided (DM basis) 108.5 mg kg^{-1} copper, 425.9 mg kg^{-1} zinc, 254.0 mg kg^{-1} manganese, 5.3 mg kg^{-1} iodine, 1.1 mg kg^{-1} cobalt, 3.3 mg kg^{-1} selenium, 25.4 KIU kg^{-1} vitamin A, 2.5 KIU kg^{-1} vitamin D, 254.4 IU kg^{-1} vitamin E.

were adapted to a 91% concentrate diet over 27 d using three transition diets (Table 1). Cattle were fed the final diet for a total of 113 d.

Daily feed deliveries were recorded and orts were collected weekly and analyzed for DM content for calculation of DMI and feed efficiency (gain:feed). Weights at day 56 and final weights were obtained with an assumed shrink of 4% used for calculating animal weights and ADG. For comparison with live performance, carcass-adjusted performance was calculated using final live weight calculated as carcass weight/58%. Animal health was monitored daily by experienced animal health technicians. Animals deemed to be "sick", based on subjective criteria such as general appearance, nasal/ocular discharge, gauntness or reluctance to move, were removed from their designated pen and presented for evaluation and treatment. A diagnosis of bovine respiratory disease was made if the animal had a rectal temperature above 40.5°C with an absence of clinical signs attributable to an organ system other than the respiratory tract. Calves were deemed to have foot rot if they were lame with interdigital swelling of the hoof. Ten days prior to trial completion, supplement was removed from LC diets in accordance with the withdrawal time specified by the experimental drug certificate. Corn and silage were increased proportionally to replace the supplement in the diet. At the conclusion of the trial, all cattle were slaughtered on the same day at a local abattoir. Carcasses were not trimmed of excess fat and did not include kidney, pelvic, or heart fat when weighed. Carcass measurements (backfat thickness, ribeye area, marbling level, warm carcass weight and percentage saleable meat) were determined as described by the Canadian Beef Grading Agency (2008). The rate and severity of liver abscess (Brown et al. 1975) were also recorded for each steer.

Statistical Analysis

Dry matter intake, ADG, gain:feed, and carcass traits were analyzed using the MIXED procedure of the SAS Institute, Inc. (1996) with pen as the experimental unit and pen within treatment as the error term. Medication (LC or MT), processing method (SR or G) and their interactions were considered in the statistical model. The incidences of foot rot and of liver abscesses were also compared using the two-sided Fisher's Exact Test from chi-square analysis. Patterns of bunk attendance monitored using the GrowSafe system were compared between treatments using individual animals as the experimental unit with the residual error as the error term. Daily deviation in duration at the bunk was calculated as average daily deviation from the mean duration. To avoid Type 1 error, treatment means were compared using the Tukey adjusted PDIFF option of SAS software. Stepwise regressions were used to determine how ADG and liver abscesses were influenced by bunk attendance variables.

RESULTS AND DISCUSSION

Performance

By experimental design, ionophore and antibiotic effects are confounded. There was no antibiotic by grain processing interaction on performance or carcass measurements, so only main effects will be discussed.

During the first 56 d of the trial, DMI was greater ($P = 0.01$) for cattle fed LC (8.8 kg d^{-1}) than for cattle fed MT (8.3 kg d^{-1}). This difference was not as large through the remainder of the trial (9.39 vs. 9.07 kg d^{-1}; $P = 0.12$), but, overall, there was a trend ($P = 0.07$) of increased DMI for cattle fed LC (9.16 kg d^{-1}) compared with cattle fed MT (8.76 kg d^{-1}). The negative effects of monensin on DMI have declined with time in previous research (Pendlum et al. 1978). Over the entire feeding period, DMI was greater ($P = 0.04$) for cattle fed LC (9.2 kg d^{-1}) than for cattle fed MT (8.8 kg d^{-1}). Reduced intake is commonly reported when monensin is fed to feedlot cattle, especially immediately following introduction (Spires et al. 1990; Galyean et al. 1992). In the six trials reported by Spires et al. (1990), in which laidlomycin was included at 3 to 12 mg kg^{-1}, DMI was not significantly affected compared with control diets, but a linear decline in DMI with increasing levels was noted. Laidlomycin fed at 6 or 12 mg kg^{-1} had a tendency to reduce DMI during the first 28 d as cattle were adapted to high-grain diets (Bauer et al. 1995). Other trials have found that laidlomycin had either no effect (Berger et al. 1991; Galyean et al. 1992) or a positive effect on DMI (Faulkner et al. 1991). In the trial of Bauer et al.

Table 2. Effect of medication and grain processing on performance of feedlot steers

	LC[z]		MT[y]			$P =$		
	SR[x]	G[w]	SR[x]	G[w]	SEM[v]	Med[u]	Proc[t]	M × P[s]
$N =$	4	4	4	4				
Initial weight (kg)	333.4	328.1	326.1	339.0	6.6	0.62	0.31	0.03
Final weight (kg)	552.4	541.1	534.8	540.4	8.2	0.29	0.72	0.32
Days 1 to 56								
56 d weight (kg)	424.4	414.7	411.4	420.8	6.2	0.59	0.98	0.15
DMI (kg d^{-1})	8.84	8.76	8.24	8.31	0.170	0.01	0.97	0.65
ADG (kg)	1.63	1.55	1.52	1.46	0.060	0.15	0.26	0.89
Gain:feed	0.183	0.176	0.185	0.175	0.004	0.96	0.06	0.77
Days 57 to 140								
DMI (kg d^{-1})	9.43	9.34	8.90	9.24	0.193	0.12	0.53	0.29
ADG (kg)	1.52	1.50	1.47	1.42	0.047	0.19	0.48	0.81
Gain:feed	0.162	0.161	0.165	0.155	0.004	0.78	0.21	0.27
Days 1 to 140								
DMI (kg d^{-1})	9.20	9.11	8.64	8.87	0.173	0.07	0.69	0.37
ADG (kg)	1.56	1.52	1.49	1.44	0.044	0.11	0.29	0.94
Gain:feed	0.170	0.167	0.173	0.162	0.003	0.80	0.06	0.28

[z]LC contained 12 mg laidlomycin propionate kg^{-1} DM and 42 mg chlortetracycline kg^{-1} DM.
[y]MT contained 30 mg monensin sodium kg^{-1} DM and 11 mg tylosin phosphate kg^{-1} DM.
[x]Diets contained steam-rolled corn.
[w]Diets contained ground corn.
[v]Standard error of treatment means.
[u]Effect of medications.
[t]Effect of grain processing.
[s]Interactive effect of medication × processing interaction.

(1995), 12 mg kg^{-1} laidlomycin reduced day-to-day variation in DMI, a measurement commonly used as an indicator of acidosis (Fulton et al. 1979; Stock et al. 1995; Gibb et al. 2001). Chlortetracycline (35 mg kg^{-1}) has increased DMI relative to control diets (Beacom et al. 1988). In the summary of trials reported by Vogel and Laudert (1994), tylosin did not affect DMI.

Intakes were similar ($P = 0.69$) between SR (8.92 kg d^{-1}) and G (8.99 kg d^{-1}) diets. When compared with dry-rolling in a large meta-analysis, steam-flaking reduced DMI. Similarly, steam-flaked corn has reduced intakes in direct comparisons (Zinn et al. 2002). More aggressively rolled (i.e., steam-flaked) grains result in increased ruminal fermentation and acid production, which is known to reduce intake (Fulton et al. 1979). Compared with typical steam-flaked corn (volume weight ~0.36 kg L^{-1}), the coarsely rolled corn used in this experiment (0.55 kg L^{-1}) would have resulted in more moderate acid production and intake suppression. As well, the small particles of the ground corn may have reduced acceptability.

The greater ($P = 0.04$) intakes of cattle fed LC through the trial contributed to a trend ($P = 0.11$) of greater ADG (1.54 vs. 1.47 kg d^{-1}) compared with MT cattle. Trends were similar, but less clear ($P = 0.39$) when performance was calculated from carcass-adjusted final live weight. In research conducted by Galyean et al. (1992), ADG of cattle receiving 31 mg kg^{-1} monensin and 12 mg kg^{-1} tylosin was similar to ADG of cattle receiving 12 mg kg^{-1} laidlomycin, neither of which differed from the control group. In receiving diets for recently weaned calves, 12 mg kg^{-1} laidlomycin suppressed DMI during the initial 56 d with no effect on ADG compared with diets containing no ionophore (Pritchard 1995). Both tylosin (Potter et al. 1985; Vogel and Laudert 1994) and chlortetracycline (Brown et al. 1975; Beacom et al. 1988) have improved ADG.

Average daily gains were not affected by grain processing ($P = 0.29$) at any time throughout the experiment, and averaged 1.48 kg d^{-1} for G and 1.53 kg d^{-1} for SR diets. Carcass-adjusted ADG was also not affected ($P = 0.40$) by processing method. As compiled in the meta analysis of Owens et al. (1997), steam-flaking corn increases energy density, but does not always increase the rate of gain due to lower intakes. However, when feeding of dry-rolled and steam-flaked corn are compared directly, ADG is often greater with steam-flaking (Zinn et al. 2002). As reported in the review of corn processing by the National Research Council (1996), energy differences between whole, rolled, and ground corn are small.

Gain:feed averaged 0.168 with no difference ($P > 0.80$) due to antibiotic supplementation. Although both laidlomycin (Spires et al. 1990) and monensin (Goodrich et al. 1984) improve feed efficiency over control diets, response was similar when they were compared with each other (Galyean et al. 1992). Both tylosin (Brown et al. 1975; Vogel and Laudert 1994) and chortetracyline (Brown et al. 1975) have improved feed efficiency in previous research. However, other experiments have found no effect of chlortetracycline (Beacom et al. 1988) and only a small response to tylosin (Potter et al. 1985).

Despite the lack of ADG response ($P = 0.26$) to corn processing, there was a trend ($P = 0.06$) toward improved gain:feed with SR compared with G corn (7.3%; 0.171 vs. 0.164). This difference was less clear ($P = 0.15$) when determined from carcass-adjusted final weight. Steam-flaking consistently increases energy density and feed efficiency compared with dry-processing (Owens 1997; Zinn et al. 2002). Using the National Research Council formula, as outlined by Owens et al. (1997), ME concentrations of SR and G corn were calculated to be 3.65 and 3.57 MCal kg^{-1}, respectively. This small difference is in contrast to the 14% average difference between steam-flaked and dry-processed corn documented in the Owens et al. (1997) summary. The lack of difference in energy content between processing methods observed in the current trial is likely due to under processing of the steam-rolled corn (0.55 kg L^{-1}). Optimum processing of steam-flaked corn has been proposed to occur at a flake density of 0.31 kg L^{-1} (Zinn et al. 2002).

Bunk Attendance

Together, increased frequency of bunk visits ($P = 0.03$) and duration per meal ($P = 0.03$) had a small ($R^2 = 0.12$) but consistent negative effect on ADG. However, daily deviation in time at the bunk did not ($P = 0.80$) affect ADG. The second stepwise regression indicated that liver abscesses also increased with increasing frequency of bunk visits ($P = 0.002$; $R^2 = 0.16$). Acidosis reduces DMI (Fulton et al. 1979; Erickson et al. 2003) and contributes to liver abscesses (Galyean and Rivera 2003), both of which can reduce performance (Brink et al. 1990). It is possible that the acidosis challenges that resulted in abscessed livers also altered eating patterns, resulting in more frequent visits to the bunk.

Patterns of bunk attendance were influenced by feed additives and processing method as well as their interactions (Table 3). Medication did not influence duration ($P = 0.79$) or frequency ($P = 0.58$) of bunk visits for cattle fed SR diets. However, with G diets, LC reduced (2.1%; $P = 0.03$) the frequency of daily visits (9.3 vs. 9.5), but increased (6%; $P < 0.001$) the duration at the bunk (135.9 vs. 124.0; interaction $P < 0.001$), resulting in increased (12.4%; $P < 0.001$) duration per meal (15.4 vs. 13.7 min). Increased frequency of meals has previously been observed in cattle supplemented with monensin compared with control (Laudert 1995; Erickson et al. 2003) or cattle fed salinomycin (Gibb et al. 2001). The reduced intakes often observed with feeding monensin are typically associated with more frequent, but smaller meals, resulting in more stable intakes (Chirase et al. 1992; Laudert 1995; Gibb et al. 2001). Daily deviation in time at the bunk was affected by medication ($P < 0.001$), processing ($P < 0.001$), and their interactions ($P = 0.02$). Variation in time at the bunk averaged 33 min d^{-1}, or 27%, which is similar to previous observations (Gibb et al. 1998, 2001). Compared with LC, monensin, reduced (9.7%; $P < 0.001$) variation for cattle fed G diet (33.7 vs. 37.3 min d^{-1}), but not ($P = 0.30$) for cattle fed SR diet (30.4 vs. 31.3 min d^{-1}). Variation in intake has been used as an indicator of subacute acidosis (Fulton et al. 1979; Stock et al. 1995). However, correlations between daily variation in time at the bunk and ADG (Gibb et al. 1998) or daily variation in DMI and feed efficiency (Stock et al. 1995) have been weak. The effect of monensin supplementation on eating behaviour (Chirase et al. 1992; Gibb et al. 2001) and lactate production (Nagaraja et al.

Table 3. Effect of medication and grain processing on patterns of bunk attendance

	LC[z]		MT[y]			$P =$		
	SR[x]	G[w]	SR[x]	G[w]	SEM[v]	Med[u]	Proc[t]	M × P[s]
$N =$	15	15	15	15				
Frequency (visits d^{-1})	8.9*c*	9.3*b*	8.8*c*	9.5*a*	0.06	0.25	0.001	0.05
Duration (min d^{-1})	114.9*c*	135.9*a*	115.3*c*	124.0*b*	0.93	0.001	0.001	0.001
Daily deviation[r] (min)	31.3*c*	37.3*a*	30.4*c*	33.7*b*	0.59	0.001	0.001	0.02
Duration $meal^{-1}$ (min)	13.6*b*	15.4*a*	13.8*b*	13.7*b*	0.11	0.001	0.001	0.001

a–c Within a row, values followed by different letters differ ($P < 0.05$).
[z]LC contained 12 mg laidlomycin propionate kg^{-1} DM and 42 mg chlortetracycline kg^{-1} DM.
[y]MT contained 30 mg monensin sodium kg^{-1} DM and 11 mg tylosin phosphate kg^{-1} DM.
[x]Diets contained steam-rolled corn.
[w]Diets contained ground corn.
[v]Standard error of treatment means.
[u]Effect of medications.
[t]Effect of grain processing.
[s]Interactive effect of medication × processing.
[r]Average daily deviation from mean duration over the course of the feeding period.

Table 4. Effect of medication and grain processing on carcass characteristics

	LC[z]		MT[y]			P =		
	SR[x]	G[w]	SR[x]	G[w]	SEM[v]	Med[u]	Proc[t]	M × P[s]
N =	60	60	60	60				
Carcass weight (kg)[r]	326.5	320.5	319.7	323.0	4.79	0.46	0.69	0.13
Dressing percentage (%)[r]	59.1	59.3	59.7	59.8	0.002	0.03	0.62	0.93
Grade fat (mm)	11.8	11.0	12.1	10.2	1.35	0.77	0.19	0.56
Average fat cover (mm)	14.1	13.2	12.5	12.2	0.77	0.01	0.28	0.55
Ribeye area (cm^2)	87.3	85.5	84.6	87.5	2.21	0.11	0.43	0.78
Quality grade[q]	2.55	2.32	2.46	2.32	0.12	0.72	0.18	0.73
Meat yield (%)[p]	56.6	57.3	58.0	58.3	0.86	0.01	0.26	0.63

[z]LC contained 12 mg laidlomycin propionate kg^{-1} DM and 42 mg chlortetracycline kg^{-1} DM.
[y]MT contained 30 mg monensin sodium kg^{-1} DM and 11 mg tylosin phosphate kg^{-1} DM.
[x]Diets contained steam-rolled corn.
[w]Diets contained ground corn.
[v]Standard error of treatment means.
[u]Effect of medications.
[t]Effect of grain processing.
[s]Effect of medication by processing interaction.
[r]Kidney, pelvic and heart fat (KPH) was fat removed before carcasses were weighed.
[q]Calculated from Canada grades, where 1 = Canada grade A, 2 = AA, and 3 = AAA.
[p]Percentage of the carcass that is red meat.

1981) are considered beneficial in minimizing subacute acidosis (Erickson et al. 2003).

Despite similar ($P = 0.69$) intakes between SR (8.92 kg d^{-1}) and G (8.99 kg d^{-1}), cattle fed G spent more (12.8%; $P < 0.001$) time at the bunk (129.9 vs. 115.1 min d^{-1}), suggesting reduced eating rates of these diets. Cattle fed G also visited the bunk more frequently (5.4%; $P = 0.001$) than cattle fed SR (9.4 vs. 8.9 visits d^{-1}). Increased fines (small particles) in the aggressively processed G diet may have reduced palatability or affected ruminal fermentation (Zinn et al. 1998) resulting in reduced pH (Fulton et al. 1979) and/or increased osmolarity (Bergen 1972) and volatile faty acid concentrations (Baile and Forbes 1974). However, enhanced ruminal fermentation is not supported by improvements in animal performance.

Carcass Traits

Dietary treatments did not affect carcass weights ($P > 0.33$), ribeye area ($P > 0.11$), quality grade ($P > 0.18$), or marbling level ($P > 0.30$; Table 4). Feeding MT resulted in increased ($P = 0.03$) dressing percentage (carcass weight without KPH fat/live weight) of carcasses (59.7 vs. 59.2%). Feeding LC resulted in increased ($P = 0.01$) fat cover resulting in lower ($P = 0.01$) meat yield compared with carcasses from cattle fed MT. Feeding laidlomycin has increased thickness of backfat in feedlot cattle in previous research (Spires et al. 1990).

Liver Abscesses

There was a trend ($P = 0.09$) of reduced liver abscesses with MT (6.5%) compared with LC (13.2%; Table 5). The prevalence of severely abscessed livers averaged 2.9% and was not influenced by medication ($P = 0.45$) or processing ($P = 1.00$).

Nagaraja and Chengappa (1998) documented several experiments that evaluated the effectiveness of antimicrobials cleared for liver abscess control by the US Food and Drug Administration. As documented by these authors, tylosin is often the most effective with reductions ranging from 60% (Potter et al. 1985) to 73% (Vogel and Laudert 1994). However, liver abscess control of feedlot cattle does not always explain performance responses with antibiotic supplementation. Chlortetracycline improves growth rates in chickens, turkeys, and swine (Canadian Food Inspection Agency 2008) that do not suffer from liver abscesses resulting from ruminal acidosis. Improved fertility in heifers on pasture fed chlortetracycline has been documented (Saltman et al. 1998; Rae et al. 2002). Besides anti-

Table 5. Effect of medication on incidence of foot rot and liver abscesses

			P =	
	MT[z]	LC[y]	Med.[x]	Proc.[w]
Foot rot (% treated)	7.5	0.8	0.02	0.42
Abscessed livers (%)	6.5	13.2	0.09	0.40
Severely abscessed livers (%)[v]	1.6	4.1	0.45	1.00

[z]LC contained 12 mg laidlomycin propionate kg^{-1} DM and 42 mg chlortetracycline kg^{-1} DM.
[y]MT contained 30 mg monensin sodium kg^{-1} DM and 11 mg tylosin phosphate kg^{-1} DM.
[x]Effect of medications.
[w]Effect of grain processing.
[v]Liver contained multiple abscesses or at least one abscesses greater than 2.5 cm in diameter.

microbial effects, chlortetracycline also affects the endocrine system (Rumsey et al. 1999, 2000). In a review of the mode of growth promotion by antibiotics, Visek (1978) documented trials in which growth responses were obtained from feeding antibiotics to both germ free and conventional animals.

Cattle fed LC had a lower incidence of foot rot (7.5% vs. 0.8%; $P = 0.02$) compared with those supplemented with MT (Table 5). *Fusobacterium necrophorum* is the primary causative organism of both foot rot and liver abscesses. Although tylosin may be more effective in preventing liver abscesses (Brown et al. 1975; Vogel and Laudert 1994), it was less effective against *Fusobacterium necrophorum* than is oxytetracycline, based on MIC data (Berg and Scanlan 1982). Differences in efficacy in the current experiment may be due to differences in diet concentration (11 mg kg^{-1} tylosin vs. 42 mg kg^{-1} tylosin chlortetracycline), absorption, or systemic distribution. Chlortetracycline included at 22 mg kg^{-1} of diet dry matter is cleared for the prevention of foot rot in feedlot cattle (Canadian Food Inspection Agency 2008).

This research documents that feeding 12.0 mg kg^{-1} laidlomycin propionate with 42 mg kg^{-1} chlortetracycline increases DMI and may enhance ADG compared with feeding 30 mg kg^{-1} monensin sodium with 11 mg kg^{-1} tylosin phosphate. Although the LC combination may not be as effective in controlling liver abscesses, it was more effective in reducing the incidence of foot rot. Steam-rolling the corn improved feed efficiency and reduced differences in feeding behaviour that were due to medications.

ACKNOWLEDGEMENTS

This study was partially supported with funds from Alpharma Inc. The help and support of technical staff involved in feeding and caring for livestock as well as compiling data is greatly appreciated.

Baile, C. A. and Forbes, J. M. 1974. Control of feed intake and regulation of energy balance in ruminants. Phys. Rev. **54**: 160–214.

Bauer, M. L., Harold, D. W., Britton, R. A., Stock, R. A. and Klopfenstein, T. J. 1995. Efficacy of laidlomycin propionate to reduce ruminal acidosis. J. Anim. Sci. **73**: 3445–3454.

Beacom, S. E., Mir, Z., Korsrud, G. O., Yates, W. D. G. and MacNeal, J. D. 1988. Effect of the feed additives chlortetracycline, monensin, and lasalocid on feedlot performance of finishing cattle, liver lesions and tissue levels of chlortetracycline. Can. J. Anim. Sci. **68**: 1131–1141.

Berg, J. N. and Scanlan, C. M. 1982. Studies of *Fusobacterium necrophorum* from bovine hepatic abscesses: Biotypes, quantitation, virulence, and antibiotic susceptibility. Am. J. Vet. Res. **43**: 1580–1586.

Bergen, W. G. 1972. Rumen osmolality as a factor in feed intake control of sheep. J. Anim. Sci. **34**: 1054–1060.

Bergen, W. G. and Bates, D. B. 1984. Ionophores: Their effect on production efficiency and mode of action. J. Anim. Sci. **58**: 1465–1483.

Berger, L. L., Trenkle, A. H., Mader, T. L. and Spires, H. R. 1991. Feedlot performance of cattle fed laidlomycin propionate, monensin or lasalocid. J. Anim. Sci. **69** (Suppl. 1): 520 (Abstr.).

Brink, D. R., Lowry, S. R., Stock, R. A. and Parrot, C. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. J. Anim. Sci. **68**: 1201–1207.

Brown, H., Bing, R. F., Grueter, H. P., McAskill, J. W., Cooley, C. O. and Rathmacher, R. P. 1975. Tylosin and chlortetracycline for the prevention of liver abscesses, improved weight gains and feed efficiency in feedlot cattle. J. Anim. Sci. **40**: 207–213.

Canadian Beef Grading Agency. 2008. [Online] Available: http://www.beefgradingagency.ca/ [2008 Feb. 08].

Canadian Council on Animal Care. 1993. Guide to the care and use of experimental animals. Vol. 1. 2nd ed. E. D. Olfert, B. M. Cross, and A. A. McWilliam, eds. CCAC, Ottawa, ON.

Canadian Food Inspection Agency. 2008. Compedium of medicated ingredients brochure. [Online] Available: http://www.inspection.gc.ca/english/animal/feebet/mib/mib10-1e.shtml. [2008 Aug. 08].

Chirase, N. K., Hutcheson, D. P. and Thompson, G. B. 1992. Effects of monensin on feeding behavior of feedlot steers and heifers. Beef Cattle Research in Texas. Texas A&M PR-4953: 17–20.

Erickson, G. E., Milton, C. T., Fanning, K. C., Cooper, R. J., Swingle, R. S., Parrott, J. C., Vogel, G. and Klopfenstein, T. J. 2003. Interaction between bunk management and monensin concentration on finishing performance, feeding behaviour, and ruminal metabolism during an acidosis challenge with feedlot cattle. J. Anim. Sci. **81**: 2869–2879.

Faulkner, D. B., Cmarik, G. F. and Spires, H. R. 1991. Evaluation of laidlomycin propionate and Synovex7 S implants for finishing steers. J. Anim. Sci. **69** (Suppl. 1): 521 (Abstr.).

Fulton, W. R., Klopfenstein, T. J. and Briton, R. A. 1979. Adaptation to high concentrate diets by beef cattle. I. Adaptation to corn and wheat diets. J. Anim. Sci. **49**: 775–784.

Galyean, M. L., Malcolm, K. J. and Duff, G. C. 1992. Performance of feedlot steers fed diets containing laidlomycin propionate or monensin plus tylosin, and effects of laidlomycin propionate concentration on intake patterns and ruminal fermentation in beef steers during adaptation to a high-concentrate diet. J. Anim. Sci. **70**: 2950–2958.

Galyean, M. L. and Rivera, J. D. 2003. Nutritionally related disorders affecting feedlot cattle. Can. J. Anim. Sci. **83**: 13–20.

Gibb, D. J., McAllister, T. A., Huisma, C. and R. D. Wiedmeier. 1998. Bunk attendance of feedlot cattle monitored with radio frequency technology. Can. J. Anim. Sci. **78**: 707–710.

Gibb, D. J., Moustafa, S. M. S., Wiedmeier, R. D. and McAllister, T. A. 2001. Effect of salinomycin or monensin on performance and feeding behaviour of cattle fed wheat- or barley-based diets. Can. J. Anim. Sci. **81**: 253–261.

Goodrich, R. D., Garret, J. E., Gast, D. R., Kirick, M. A., Larson, D. A. and Meiske, J. C. 1984. Influence of monensin on the performance of cattle. J. Anim. Sci. **58**: 1484–1498.

Laudert, S. B. 1995. Feeding behaviour of finishing steers. Pages 31–35 *in* Symposium: Intake by feedlot cattle. P–942, Oklahoma Agric. Exp. Stn.

National Research Council. 1996. Nutrient requirements of beef cattle. 7th ed. National Academy Press, Washington, DC.

Nagaraja, T. G. and Chengappa, M. M. 1998. Liver abscesses in feedlot cattle: A review. J. Anim. Sci. **76**: 287–298.

Nagaraja, T. G., Avery, T. B., Barley, E. E., Roof, S. K. and Dayton, A. D. 1982. Effect of lasalaocid, monensin or thiopeptin on lactic acidosis in cattle. J. Anim. Sci. **54**: 649–658.

Owens, F. N., Secrist, D. S., Hill, J. W. and Gill, D. R. 1998. Acidosis in cattle: A review. J. Anim. Sci. **76**: 275–286.

Owens, F. N., Secrist, D. S., Hill, J. W. and Gill, D. R. 1997. The effect of grain source and grain processing on performance of feedlot cattle: A review. J. Anim. Sci. **75**: 868–879.

Pendlum, L. C., Boling, J. A. and Bradley, N. W. 1978. Levels of monensin with and without tylosin for growing-finishing steers. J. Anim. Sci. **47**: 1–5.

Potter, E. L., Wray, M. I., Muller, R. D., Grueter, H. P., McAskill, J. and Young, C. 1985. Effect of monensin and tylosin on average and daily gain, feed efficiency and liver abscess in feedlot cattle. J. Anim. Sci. **61**: 1058–1068.

Pritchard, R. H. 1995. Dosages of laidlomycin propionate for receiving and growing diets fed to steer calves. [Online] Available: http://ars.sdstate.edu/beefext/BeefReports/1995/95-12.htm [2007 May 25].

Rae, D. O., Ramsey, K. H. and Morrison, R. L. 2002. Effect of chlortetracycline in a trace mineral salt mix on fertility traits in beef cattle females in Florida. J. Anim. Sci. **80**: 880–885.

Saltman, R. L., Chenoweth, P. J., Rae, D. O., Genho, P. C., Moore, S. A. and Crosby, C. E. 1998. Effects of an oral antibiotic on fertility in range beef cattle. Bov. Pract. **33**: 121–123.

SAS Institute, Inc. 1996. SAS/STAT® software: Changes and enhancements through release 6.11. SAS Institute, Inc., Cary, NC.

Schwartzkopf-Genswein, K. S., Huisma, C. and McAllister, T. A. 1999. Validation of a radio frequency identification system for monitoring the feeding patterns of feedlot cattle. Livest. Prod. Sci. **60**: 27–31.

Spires, H. R., Olmsted, A., Berger, L. L., Fontenot, J. P., Gill, D. R., Riley, J. G., Wray, M. I. and Zinn, R. A. 1990. Efficacy of laidlomycin propionate for increasing rate and efficiency of gain by feedlot cattle. J. Anim. Sci. **68**: 3382–3391.

Stock, R. A., Laudert, S. B., Stroup, W. W. and Larsen, E. M. 1995. Effect of monensin and monensin and tylan combination on feed intake variation of feedlot steers. J. Anim. Sci. **73**: 39–44.

Visek, W. J. 1978. The mode of growth promotion by antibiotics. J. Anim. Sci. **46**: 1447–1469.

Vogel, G. J. and Laudert, S. B. 1994. The influence of Tylan7 on liver abscess control and animal performance – A 40 Trial Summary. J. Anim. Sci. **72** (Suppl.): 293 (Abstr.).

Zinn, R. A. 1990. Influence of flake density on the comparative feeding value of steam-flaked corn for feedlot cattle. J. Anim. Sci. **68**: 767–775.

Zinn, R. A., Alvarez, E. G., Montano, M. F., Plascencia, A. and Ramirez, J. E. 1998. Influence of tempering on the feeding value of rolled corn in finishing diets for feedlot cattle. J. Anim. Sci. **76**: 2239–2246.

Zinn, R. A., Owens, F. N., and Ware, D. R. 2002. Flaking corn: processing mechanics, quality standards, and impacts on energy availability and performance of feedlot cattle. J. Anim. Sci. **80**: 1145–1156.