Use of Technology and Implications for the Environment

Jim MacDonald[1,2] Andy Cole[3], and Kristin Hales[3]

[1]Texas AgriLife Research, Amarillo, [2]West Texas A&M University, Canyon, [3]USDA-ARS, Bushland

Introduction

The use of technology in beef cattle production has dramatically changed animal performance indices over the past 30+ years. Several technologies such as implants, ionophores, and antimicrobial drugs have wide adoption rates in the United States. Other more recent technologies such as beta-agonists currently have lower adoption rates, but have the potential to further impact beef production in the future. The impacts of technologies on animal performance are well documented elsewhere (Wileman et al., 2009) and are beyond the scope of this paper. The net result of these technologies has increased carcass weights and feed efficiency.

Society is increasingly concerned about the impacts of animal production practices on the environment, human health, and animal health. This concern has resulted in increased monitoring and proposed regulations by the government. Both greenhouse gasses and ammonia emissions are of concern. There has also been increased interest by the public in natural beef production systems as an alternative to conventional systems. While inconsistent in definition, natural productions systems generally limit the use of technologies. Little information relating production technologies to environmental impacts is available. Therefore, our objective was to estimate the impacts of production technologies (implants, ionophores, beta-agonists, and antimicrobials) on environmental factors such as ammonia and greenhouse gasses.

Effects of technological advancements on environmental impacts of feedyards

Although most of the technological advancements we have seen over the past 30+ years were designed to improve animal performance, they could have also altered the effects of feedyards on the environment. In order to estimate the effects of technological advancement on beef cattle feeding environmental effects we utilized three approaches. The first was to utilize the updated 2000 Beef Cattle NRC program to calculate animal performance and retained protein as a result of using implants and ionophores. The second strategy developed models that tracked changes in animal performance and environmental indices over approximately the past 30 years that may be related to changes in technology. The third was to utilize assumptions from the literature to relate implant and ionophore use to animal performance, ammonia losses, and greenhouse gas emissions.

1. *NRC model predictions.*

The latest version of the beef cattle NRC (2000) accounts for the use of both implants and ionophores. Impacts on feed intake (increased for implants, decreased for ionophore), ADG (increased for both implants and ionophores), and feed efficiency (increased for both implants and ionophores) are accounted for in the model. The model deals with implants by increasing final BW 150 lbs (70 kg) for steers receiving a combination of estradiol and trenbolone acetate compared to steers receiving no implants. Ionophore effects are taken into account by increasing dietary NEm by 12%. The model also provides estimated retained protein (reported herein as retained nitrogen). If the CP of a diet is known and accurate estimates of DMI are provided, the model can be used to estimate nitrogen intake and nitrogen retention. The difference of these values provides an estimate of nitrogen excretion.

To evaluate the impacts of implants and ionophores on nitrogen losses, a traditional diet fed in the Southern Great Plains was developed and evaluated in the NRC model. The diet consisted of 83.25% steam-flaked corn, 7.5% alfalfa hay, 3.0% molasses, 4.0% cottonseed meal, 1.0% urea, and 1.25% limestone. The diet was formulated to contain 13.5% CP and the cottonseed meal and urea were adjusted to achieve a degradable intake protein balance of 0 using a microbial efficiency of 14% in level 1 of the NRC model. Nutrient concentrations for all ingredients were obtained from NRC book values. For all evaluations, an initial BW of 750 lb was used. Final BW was increased 150 lb for implant use which assumes the use of a combination implant. The evaluation was conducted using a mean BW which differed with implant use. Intakes were adjusted by decreasing DMI 4% in the presence of ionophores (NRC, 2000) and increasing DMI by 1.2 lb when implants were used (Wileman et al., 2009). The NRC model was used to estimate ADG for the response to ionophores. However, the response to implants was less than expected based on a recent literature review (Wileman et al., 2009). Therefore, NE adjusters were used to alter ADG so that the use of implants resulted in a 9% improvement in feed efficiency (Wileman et al., 2009) for the comparison of implants in diets containing monensin. Days on feed were calculated from estimates of animal performance and projected final BW. The model was primarily used to predict retained nitrogen. Assumed DMI and dietary CP concentration was used to determine nitrogen intake, and N excretion was calculated from the difference of N intake and retained N. Total excreted N was calculated from daily N excretion estimates multiplied by calculated days on feed. For the purposes of this evaluation, it is assumed that 60% of excreted N is volatilized as ammonia. Hot carcass weight was estimated using a constant dressing percentage of 63% for all evaluations. Ammonia loss per pound of carcass weight was calculated by dividing the total calculated ammonia loss by carcass weight.

The results of the evaluation are shown in Table 1. By design, the use of implants increased ADG by 15% and feed efficiency by 9% whereas the use of ionophores increased ADG by 1%, but increased feed efficiency by 5%. Implants increased days on feed by 20 days to achieve the additional BW. Effects of implants and ionophores on nitrogen balance were affected by impacts on DMI and days on feed. Ionophores had little effect on retained N, whereas implants increased retained N by 16%. However, implants also increased N excretion as a result of increased N intake and greater days on feed. The net effect was that ionophores resulted in a small decline in the amount of ammonia projected to be lost over the feeding period, whereas implants increased ammonia volatilization by 6 lb per head. However, if increases in carcass weight are also accounted for, implants result in only a small increase in ammonia loss per pound of carcass weight produced. If monensin and implants are used in combination, more carcass weight is produced while the amount of ammonia lost per pound of carcass weight is constant. These observations suggest that implants and ionophores allow for increased beef production without increasing ammonia losses when expressed per unit of carcass weight.

Table 1. Calculated effects of ionophores and implants on animal performance and environmental variables using the 2000 Beef NRC model.

Item	No Monensin	No Monensin	+ Monensin	+ Monensin
	w/o implant	+ implant	w/o implant	+ implant
Initial BW, lb	750	750	750	750
Mean BW, lb	975	1050	975	1050
Final BW, lb	1200	1350	1200	1350
ADG, lb	3.51	4.04	3.55	4.09
DMI, lb/d	21.6	22.8	20.8	22.0
Feed DM:Gain	6.16	5.64	5.86	5.37
Days on Feed	128	148	127	147
N intake, lb/d	0.467	0.492	0.449	0.475
Retained N, lb/d	0.066	0.078	0.067	0.078
Excreted N, lb/d	0.401	0.414	0.382	0.397
N excreted, lb/hd	51.3	61.3	48.5	58.3
NH_3-N, lb/hd[1]	30.8	36.8	29.1	35.0
Dressing %	63.0	63.0	63.0	63.0
Carcass weight, lb	756	850	756	850
lb NH_3-N / lb HCW	0.041	0.043	0.038	0.041

[1]Assumes 60% of excreted N is volatilized as NH_3-N.

2. Historic changes in animal performance.

This model used animal performance in Kansas feedyards obtained from the 1990 to 2007 Kansas State University Focus on Feedlots data set. In addition, typical values expected in 1980 were extracted from the brain cells of one author. From the performance data we then estimated carcass weights, fecal output, nitrogen excretion, ammonia emissions, and methane emissions based on the following assumptions:

1. Ration DM, gross energy (GE), and N digestibilities were 72%,
2. Dressing percent was 62% of final weight,
3. Dietary CP concentration was 12.5 or 13.5 %,
4. N retention was 15% of N intake,
5. Ammonia volatilization losses were 80 % of urinary N excretion,
6. Methane losses were 3.5% of GE intake.

These data were then regressed against year using the Proc REG procedure of SAS in order to estimate average annual changes in each variable. In this data set it was assumed that average changes in production, etc. were the results of a combination of improved technologies, improved management, and advances in animal genetics.

As noted in Table 2, since 1980 the average days on feed has increased approximately 0.416 d /year ($P < 0.07$), slaughter weight has increased 7.71 lb/year ($P < 0.001$), ADG has increased 0.025 lb/year ($P < 0.001$), and feed DM /gain has decreased 0.056 lb/year ($P < 0.001$). Although not a significant change, total DMI for the entire feeding period has increased about 5.585 lb/year ($P = 0.19$); due in part to the longer feeding periods. Despite longer feeding periods, calculated total fecal DM output per head has not changed significantly ($P < 0.26$: slope of 0.969 lbs/year), but calculated lbs of fecal DM / lb of carcass weight has decreased 0.0054 lbs per year ($P < 0.002$). These calculations assume that dietary DM digestibility remained relatively constant over the years, which may be incorrect. Since 1980 the percentage of forage in finishing diets has probably decreased; which would lead to an increase in dietary DM digestibility. Assuming fecal output is directly related to the quantity of manure collected from the pens, then total manure collected per head on feed has changed little over time; however, manure production per unit of BW gain or carcass weight has probably decreased.

Calculated ammonia and enteric methane emissions per head tended ($P < 0.26$) to increase between 1980 and 2007. However emissions per lb of carcass weight have significantly decreased ($P < 0.012$).

Table 2. Regression lines of animal performance data from the KSU Focus on Feedlots in years 1990 to 2007.

Y variable	Est. 1980 value	Slope	R^2	P value <
Days on feed	137	0.416	0.19	0.069
Slaughter weight, lbs	1,050	7.710	0.796	0.001
Average daily gain, lbs	2.75	0.0201	0.677	0.001
Feed DM:gain	7.50	-0.056	0.781	0.001
Total wt gain, lb	376.8	4.26	0.806	0.001
DM intake, lb/head	2,856	3.92	0.078	0.261
Gain:DM intake	0.129	0.0013	0.786	0.001
Carcass wt., lb	650.0	3.202	0.544	0.001
Carcass gain/lb DMI	0.227	0.0012	0.436	0.003
Feces DM, lb/head	703.0	0.969	0.077	0.265
Feces DM, lb/lb of carcass wt.	1.081	-0.0032	0.362	0.010
Feces DM, lb/day	5.21	-0.0097	0.506	0.001
N excreted, lb/head	515.5	0.719	0.078	0.26
NH_3-N, lb/head	303.3	0.423	0.078	0.26
NH_3-N/lb carcass wt.,	0.467	-0.0014	0.362	0.012
CH_4, mcal/head	443.2	0.618	0.0785	0.26
CH_4/lb carcass wt.	0.682	-0.002	0.362	0.012

In our second model we developed an EXCEL spreadsheet to estimate the effects of ionophores, implants, and beta-agonists on animal performance and environmental factors. The assumptions in Table 3 were used in the model.

Table 3. Assumptions used in the EXCEL model to estimate effects of ionophores, implants, and beta-agonists on animal performance and environmental variables.

Item	Baseline	Ionophore effect	Implant effect	Beta-agonist effect
Average daily gain, lb	2.75	No effect	Increased 12%[1]	Increased 3.63% [2]
Feed DM:gain	7.5	Decreased 6 % [3]	Decreased 6 %[1]	Decreased 3.91% [2]
DM and N digestibility, %	72%	Increased 3% [3]	No effect	No effect
Enteric CH_4 emissions	3.5% of GE intake	Decreased 20% during first month or 5% overall[4]	No effect	No effect
NH_3 emissions	80% of urinary N	Indirect effect	Indirect effect	Indirect effect

[1] Herschler, et al., 1995
[2] Elam, et al., 2009
[3] Tedeschi et al., 2003.
[4] Guan et al., 2006

Table 4. Calculated effects of ionophores and implants on animal performance and environmental variables assuming a constant 150 days on feed.

Item	No Monensin w/o implant	No Monensin + implant	+ Monensin w/o implant	+ Monensin + implant
Diet % forage	12	12	12	12
Diet % CP	12.5	12.5	12.5	12.5
DMD, %	72	72	74	74
ADG, lb	2.75	3.08	2.75	3.08
DM:Gain	7.50	7.05	7.05	6.63
DMI, lb/d	20.63	21.71	19.39	20.42
Feces, lb/d	5.78	6.08	5.04	5.31
Fecal N, g/d	52.4	55.2	45.7	48.2
Urine N, g/d	106.7	112.3	103.8	109.3
NH_3-N, g/d	85.3	89.8	83.0	87.4
NH_3-N, lb/head	28.2	29.6	27.4	28.8
CH4, mcal/d	1.48	1.55	1.31	1.38
CH4, mcal/head	221.5	233.2	196.3	206.8
Diet % forage	7	7	7	7
Diet % CP	12.5	12.5	12.5	12.5
DMD, %	76	76	79	79
ADG, lb	3.0	3.36	3.00	3.36
DM:Gain	6.50	6.11	6.11	5.74
DMI, lb/d	19.5	20.53	18.33	19.29
Feces, lb/d	4.68	4.93	3.85	4.05
Fecal N, g/d	42.5	44.7	34.9	36.7
Urine N, g/d	107.9	113.6	106.4	112.0
NH_3-N, g/d	86.3	90.9	85.1	89.6
NH_3-N, lb/head	28.5	29.9	28.1	29.6
CH_4, mcal/d	1.40	1.47	1.24	1.30
CH_4, mcal/head	209.4	220.5	185.6	195.3
Diet % forage	7	7	7	7
Diet % CP	13.5	13.5	13.5	13.5
DMD, %	76	76	79	79
ADG, lb	3.00	3.36	3.00	3.36
DM:Gain	6.50	6.11	6.11	5.74
DMI, lb/d	19.50	20.53	18.33	19.29
Feces, lb/d	4.68	4.93	3.85	4.05
Fecal N, g/d	45.9	48.3	37.7	39.7
Urine N, g/d	116.5	122.7	114.9	120.9
NH_3-N, g/d	93.2	98.2	92.0	96.7
NH_3-N, lb/head	30.8	33.23	30.3	31.9
CH_4, mcal/d	1.40	1.47	1.24	1.30
CH_4, mcal/head	209.4	220.5	185.6	195.3

Model 2 Observations : Assuming a constant 150 days on feed

Assuming that the number of days on feed were constant at 150, the following observations were noted using the second model (Table 4).

Ionophore Effects

When the dietary forage content was 12% and CP content was 12.5% (DM basis) additions of an ionophore improved DM:gain ratio from 7.5 to 7.05, decreased fecal DM output by 0.74 lb/day (equal to 111 lb/head over a 150-d feeding period), decreased N excretion by 9.6 g/d (equal to 3.17 lb/head over 150 days), decreased estimate NH_3-N emissions by 0.8 lb/head, decreased enteric CH_4 emissions by 25.2 mcal/head (equal to 2,667 liters).

However, it is easy to argue that the feeding of ionophores has allowed nutritionists to formulate diets with lower fiber concentrations. Based on the premise that the ionophore technology allows us to feed lower forage concentrations in finishing diets, then a logical comparison to use to gauge the value of the technology would be to compare the 12% forage/12.5% CP diet with no ionophore to a 7% forage/12.5% CP diet with an ionophore. Under that scenario, the feeding of an ionophore has the following effects:

1. Increased ADG from 2.75 to 3.00 lb
2. Decreased DM:gain ratio from 7.50 to 6.11
3. Decreased fecal DM output from 5.78 to 3.85 lb/day (equal to 289.5 lb per head)
4. Decreased N excretion from 159.1 to 141.3 g/day (equal to 5.87 lb/head)
5. Had no effect on daily (85.3 vs. 85.1 g/d) or total (28.2 v 28.1 lb/head) NH_3-N emissions,
6. Decreased enteric CH_4 emissions from 221.5 to 185.6 mcal /head (3,798 liters less per head)
7. Decreased P intake (7.13 vs. 6.33 lb/head), manure P (6.42 vs. 5.70 lb/head), and manure N (22.4 vs. 18.3 lb/head) but tended to decrease manure N:P ratio (3.49 vs. 3.21)(data not shown).

Implant Effects

Based on our calculations, when the dietary forage content was 12% and CP content was 12.5% the use of growth promoting implants increased ADG from 2.75 to 3.08 lb/day, decreased DM:gain ratio from 7.5 to 7.05 and had little or no effect on total fecal output, ammonia emissions, or enteric CH_4 emissions.

It is possible to argue that the use of implants has increased protein requirements. Based on the premise that we need to feed higher protein diets when implants are used, we can compare the 7% forage/12.5% CP diet with no implant calculations to the 7% forage/13.5% CP diet with implant calculations. Under that scenario, the use of an implant had the following calculated effects:

1. Increased ADG from 3.00 to 3.36 lb
2. Decreased DM:gain ratio from 6.50 to 6.11
3. Increased feces DM output from 4.68 vs. to 4.93 lb/day
4. Increased N excretion from 150.4 to 171.0 g/day
5. Increased daily NH_3-N emissions (86.3 vs. 98.2 g/d)
6. Increased enteric CH_4 emissions from 209.4 to 220.5 mcal /head,

Additive Effects of Ionophores and Implants

Today we commonly feed both ionophores and implants to finishing cattle. When the dietary forage was 12% and the CP content was 12.5% the combined use of ionophores and implants increased ADG from 2.75 to 3.08 lbs/day, improved DM:gain ratio from 7.5 to 6.63, decreased fecal DM output from 5.78 to 5.31 lb/day, had little or no effect on N excretion (159.1 to 157.5 g/d) or ammonia emissions (28.2 to 28.8 lb/head), and decreased enteric CH_4 emissions from 221.5 to 206.8 mcal/head (1555 liters less per head).

If we base our comparisons on the earlier mentioned assumptions, we can compare the 12% forage/12.5% CP dietary regimen with no ionophores or implant to the 7% forage /13.5% CP with ionophore and implant. Under that scenario, the use of an ionophore and implant combination had the following calculated effects:

1. Increased ADG from 2.75 to 3.36 lb
2. Decreased DM:gain ratio from 7.50 to 5.74
3. Decreased feces DM output from 5.78 to 4.05 lb/day (260 lb/head decrease)
4. Slightly increased N excretion from 159.1 to 160.6 g/day
5. Increased daily NH_3-N emissions (85.3 vs. 96.7 g/d) (3.78 lb/head increase)
6. Decreased enteric CH_4 emissions from 221.5 to 195.3 mcal /head (2772 liters less per head).

Additive Effects of Ionophores, Implants, and a beta-agonist – constant days on feed

The effects of the combination of an ionophore, implant, and beta-agonist, assuming a constant 150 days on feed are presented in Table 5. We assume three differing scenarios: 1) diet forage content and CP are constant at 12 and 12.5% but DM digestion improves 3%, 2) dietary forage content is decreased to 7% but CP is 12.5%, and 3) dietary forage is decreased to 7% and dietary CP is increased to 13.5%. Using these three scenarios, use of these technologies in combination had the following effects:

1. Increased ADG 16 to 26%,
2. Decreased feed DM:gain ratio 18 to 36%,
3. Decreased daily and total DMI 2 to 7%,
4. Increased total BW gain in150 days by 66 to 109 lb.,
5. Decreased fecal DM output per head fed by 73 to 261 lbs.
6. Decreased total N excretion per head fed by 0 to 8%,

7. Increased NH_3-N emissions per day, and per head fed, but decreased NH_3-N emissions per 100 lb of BW gain by 11 to 17%,
8. Decreased CH_4 emissions per head by 8 to 14% and CH_4 emissions per unit of weight gain by 25 to 44%,
9. Decreased manure P by 1 to 7% and manure P per unit of BW gain by 18 to 36%.
10. Assuming nitrous oxide (N_2O) emission are 1% of excreted N (EPA, 2009), had little or no effect on N_2O emissions.

Table 5. Calculated effects of ionophores, implants, and beta-agonist combinations on animal performance and environmental variables assuming a constant 150 days on feed .

Item	No Monensin, implant or beta-agonist	Monensin + implant + beta-agonist	Monensin + implant + beta-agonist	Monensin + implant + beta-agonist
Diet % forage	12	12	7	7
Diet % CP	12.5	12.5	12.5	13.5
DMD, %	72	74	79	79
ADG, lb	2.75	3.19	3.48	3.48
DM:Gain	7.50	6.37	5.52	5.52
DMI, lb/d	20.63	20.33	19.20	19.20
DOF	150	150	150	150
Total DMI, lb/head	3,095	3,049	2,880	2,880
Total BW gain, lb	413	479	522	522
Feces DM, lb/d	5.78	5.29	4.03	4.03
Feces DM, lb/head	866	793	605	605
Fecal N, g/d	52.6	48.0	36.6	39.5
Urine N, g/d	106.7	108.8	111.5	120.4
N Excretion, lb/head	52.6	51.8	48.9	52.8
NH_3-N, g/d	85.3	87.1	89.2	96.3
NH_3-N, lb/head in 150 days	28.2	28.8	29.5	31.8
NH_3-N, lb/100 lb BW gain	6.83	6.01	5.64	6.09
CH_4, mcal/d	1.48	1.37	1.30	1.30
CH_4, mcal/head	221.5	205.9	194.4	194.4
CH_4, mcal/100 lb BW gain	53.7	43.0	37.2	37.2
Manure P, lb/head	8.35	8.23	7.78	7.78
Manure N, lb/head	24.36	23.03	19.45	21.01
Manure N:P ratio	2.92	2.80	2.50	2.70
Manure P, lb/100 lb BW gain	2.03	1.72	1.49	1.49

Model 2 Observations : Assuming a constant body weight gain

Additive Effects of Ionophores, Implants, and a beta-agonist – constant BW gain

The effects of the combination of an ionophore, implant, and beta-agonist, assuming a constant BW gain of 500 lb are presented in Table 6. As noted previously we assumed three differing scenarios: 1) diet forage content and CP are constant at 12 and 12.5% but DM digestion improves 3%, 2) dietary forage content is decreased to 7% but CP is held constant at 12.5%, and 3) dietary forage is decreased to 7% and dietary CP is increased to 13.5%. Using these three scenarios, use of these technologies had the following effects:

1. Increased ADG 16 to 26%,
2. Decreased feed DM:gain ratio 18 to 36%,
3. Decreased daily DMI by 2 to 7% but total DMI per head by 15 to 26 %,
4. Decreased time required to gain 500 lbs by 25 to 38 days,
5. Decreased fecal DM output per head fed by 222 to 471 lbs.
6. Decreased total N excretion per head fed by 18 to 36%,
7. Increased NH_3-N emissions per day, but decreased NH_3-N emissions per head fed by 14 to 21%, and NH_3-N emissions per 100 lb of BW gain by 11 to 21%,
8. Decreased CH_4 emissions per head by 8 to 14% and CH_4 emissions per unit of weight gain by 25 to 44%,
9. Decreased total manure P and manure P per unit of BW gain by 18 to 36%.
10. Decreased estimated nitrous oxide emissions.

Effects of metabolizable protein status on ammonia emissions

In the early days of cattle feeding most nutritionists formulated diets based on the crude protein requirements. Today, we are capable of formulating diets based on the separate protein needs of the ruminal microbial population (ruminally degradable protein – DIP) and the animal (metabolizable protein – **MP**). Metabolizable protein is defined as the true protein absorbed by the intestine and is comprised of microbial protein produced in the rumen and feed protein that escapes the stomach undigested. Using NRC (2000) equations we calculated MP intakes and requirements for cattle fed at two commercial feedyards over a 12-month period (Cole and Todd, 2009). Metabolizable protein-N status (MPN-status: MPN = MP / 6.25) was then calculated as the difference between MPN intake and the MPN required for maintenance and growth. For comparison, the resulting data were divided into four approximately equal quadrants designated as Deficient, Adequate, High, or Excessive MPN-status). The relationship between MPN-status and N volatilization losses were determined using the PROC REG procedure of SAS (SAS Institute Inc., Cary, NC).

The effects of MPN-status on N metabolism are presented in Table 7. Calculated ADG tended to be lower in cattle on MP-Deficient diets due to slightly lower DMI. Nitrogen intake increased with increasing MPN-status as did urinary N excretion, total N excretion, and N volatilization losses. Nitrogen retention and fecal N excretion were similar for the four MPN-status categories. Based on previous controlled studies (Cole et al., 2005), these results would be expected. In cattle on MPN-Deficient diets N volatilization was approximately 50% of urinary N excretion; whereas, when diets were adequate in MP, N volatilization losses were greater than 90% of urinary N excretion. Nitrogen captured in manure, as a percentage of fed N, decreased with increasing MPN-status. These results illustrate that when diets are balanced for MP, emissions of ammonia can be decreased and the manure N:P ratio may be increased giving it a higher fertilizer value.

Regression analysis indicated that the relationship between MPN-status and N volatilization losses was best represented by two linear equations; one calculated for cattle on MPN-Deficient diets and one for those on MPN-Adequate to MPN-Excessive diets (Table 8). When MP intake was less than required, N volatilization losses were not significantly affected by N intake (i.e. the slope of the regression line was not significantly different from 0). However, when MP intake was Adequate to Excessive, N volatilization losses increased linearly ($P < 0.001$).

Table 6. Calculated effects of ionophores, implants, and beta-agonist combinations on animal performance and environmental variables assuming a constant BW gain of 500 lb.

Item	No Monensin, implant or beta-agonist	Monensin + implant + beta-agonist	Monensin + implant + beta-agonist	Monensin + implant + beta-agonist
Diet % forage	12	12	7	7
Diet % CP	12.5	12.5	12.5	13.5
DMD, %	72	74	79	79
ADG, lb	2.75	3.19	3.48	3.48
DM:Gain	7.50	6.37	5.52	5.52
DMI, lb/d	20.63	20.33	19.20	19.20
DOF	182	157	144	144
Total DMI, lb/head	3,755	3,192	2,765	2,765
Total BW gain, lb	500	500	500	500
Feces DM, lb/d	5.78	5.29	4.03	4.03
Feces DM, lb/head	1,050	828	579	579
Fecal N, g/d	52.4	48.0	36.6	39.5
Urine N, g/d	106.7	108.8	111.5	120.4
N Excretion, lb/head	63.7	54.1	46.8	50.6
NH_3-N, g/d	85.3	87.1	89.2	96.3
NH_3-N, lb/head	34.2	30.0	28.2	30.5
NH_3-N, lb/100 lb BW gain	6.83	6.01	5.64	6.09
CH_4, mcal/d	1.48	1.37	1.30	1.30
CH_4, mcal/head	268.5	215.1	186.2	186.2
CH_4, mcal/100 lb BW gain	53.7	43.0	37.2	37.2
Manure P, lb/head	10.13	8.60	7.45	7.45

Manure N, lb/head	29.52	24.06	18.63	20.12
Manure N:P ratio	2.92	2.80	2.50	2.70
Manure P, lb/100 lb BW gain	2.03	1.72	1.49	1.49

Table 7. Effects of metabolizable protein-nitrogen (MPN) intake status on N metabolism averaged over both feedyards.

Item	Deficient	Adequate	High	Excessive
MPN intake – MPN required	-10.70	8.87	19.26	27.65
Ration composition				
N, %	1.83	2.13	2.36	2.41
P, %	0.36	0.36	0.33	0.52
N:P ratio	5.02	6.10	7.36	5.85
Manure composition				
N, %	2.95	2.95	2.92	2.65
P, %	0.74	0.85	0.78	0.98
N:P ratio	4.02	3.59	3.92	2.69
Calc. ADG, kg	1.41	1.48	1.45	1.44
DMI, kg	7.72	7.90	7.88	8.01
DMI / Calc. ADG	5.51	5.36	5.42	5.46
N intake, g/d	140.2	168.6	178.3	191.3
N gain, g/d	24.3	25.5	24.7	24.6
N digestion, %	64.5	70.3	68.0	75.3
Fecal N, g/d	48.7	49.2	57.4	47.7
Urine N, g/d	67.3	93.9	96.2	119.0
Urine N, % of N excreted	57.3	65.0	63.3	71.6
N volatilization, % of N intake	21.0	41.2	45.0	53.9
N volatilization, g/head daily	29.8	69.5	79.9	103.1
N volatilization, % of urine N	46.6	89.8	104.9	93.3
Manure N, % of N intake	56.0	40.9	39.8	33.9

Table 8. Regression of metabolizable protein-nitrogen status (MPNstatus) vs. N volatilization losses averaged over two feedyards (Cole & Todd, 2009)[1]

Dependent variable & Data set	Equation	R^2	RMSE	$P <$
N loss, g/head				
All	47.7 + 1.444 (MPNstatus)	0.59	17.85	0.001
MPNstatus negative	29.30 – 0.343 (MPNstatus)	0.03	12.50	0.500
MPNstatus positive	40.14 + 1.852(MPNstatus)	0.53	17.70	0.001
N loss, % of N intake				
All	30.24 + 0.602 (MPNstatus)	0.43	10.17	0.001
MPNstatus negative	17.57 – 0.535 (MPNstatus)	0.12	8.47	0.131
MPNstatus positive	26.62 + 0.801(MPNstatus)	0.41	9.89	0.001

[1] MPNstatus = Daily metabolizable protein-nitrogen intake – daily metabolizable protein-nitrogen required. RMSE = Root mean square error.

Summary and Conclusions

Technologies have contributed to improved animal performance over the past 30 years by increasing dietary energy concentration, weight gain, and carcass weight with marginal increases in DMI. The improvements in feed efficiency observed over this time period likely would not have been possible without the adoption of growth enhancing technologies. While the emission of ammonia and greenhouse gasses produced per head have remained stable, the emissions have been reduced when expressed on per pound of carcass weight. Therefore, we conclude that the use of growth enhancing technologies are vital in reducing the carbon footprint of a serving of beef.

Literature Cited

Cole, N. A., R. N. Clark, R. W. Todd, C. R. Richardson, A. Gueye, L. W. Greene, and K. McBride. 2005. Influence of dietary crude protein concentration and source on potential ammonia emission from beef cattle manure. J. Anim. Sci. 83:722-731.

Cole, N. A. and R. W. Todd. 2009. Nitrogen and phosphorus balance of beef cattle feedyards. Proc. Texas Manure Management Issues Conference. Sept. 29-30, 2009. Austin, TX.

EPA.2009. Environmental Protection Agency. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007. Washington, D.C.: U.S. Environmental Protection Agency. Available: http://epa.gov/climatechange/emissions/usinventoryreport.html.

Elam, N. A., J. T. Vasconcelos, G. Hilton, D. L. VanOverbeke, T. E. Lawrence, T. H. Montgomery, W. T. Nichols, M. N. Streeter, J. P. Hutcheson, D. A. Yates, and M. L. Galyean. 2009. Effect of zilpaterol hydrochloride duration of feeding on

performance and carcass characteristics of feedlot cattle. J. Anim. Sci. 87:2133-2141.
Elmund, G.K., Morrison, S.M., Grant, D.W., Nevins, S.M., 1971. Role of excreted chlortetracycline in modifying the decomposition process in feedlot waste. Bull. Environ. Contam Toxicol. 6, 129-132.
Guan, H., K. M. Wittenberg, K. H. Ominski, and D. O. Krause. 2006. Efficacy of ionophores in cattle diets for mitigation of enteric methane. J. Anim. Sci. 84:1896-1906.
Herschler, R. C., A. W. Olmsted, A. J. Edwards, R. L. Hale,T. Montgomery, R. L. Preston, S./ J. Bartle, and J. J. Sheldon. 1995. Production responses to various doses and ratios of estradiol benzoate and trenbolone acetate implants in steers and heifers. J. Anim. Sci. 73: 2873-2881.
NRC. 2000. Nutrient Requirements of Beef Cattle. 7^{th} Revise Ed. Update 2000. National Academy Press, Washington, D.C.
Tedeschi, L. O., D. G. Fox, adn T. P. Tylutki. 2003. Potential environmental benefits of ionophores in ruminant diets. J. Environ. Quality 32;1591-1602.
Wileman, B.W., D.U. Thomson, C.D. Reinhardt, and D.G. Renter. 2009. Analysis of modern technologies commonly used in beef cattle production: Conventional beef production versus nonconventional production using meta-analysis. J. Anim. Sci. 87:3418-3426.

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