Beef Production: Changes Over the Years

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Abstract

Modern beef production systems have seen significant changes in the last 30 years, from number of ranches and feedlots to the use of different technologies. Data from key beef production inputs and outputs were gathered from the time of peak beef cattle numbers in 1975 and compared to data from 2008. The majority of the change occurring in the last 30 years has been from the development and implementation of beef production technologies. The beef industry has significantly reduced its natural resource burden in terms of land mass and number of animals used, all while increasing production. One of the changes in the last 30 years in beef production has been the emergence of natural and organic beef production. These production systems do not allow many of the technologies used in conventional beef production, and the discussion of these technologies appears to be a major driver of future beef production. Therefore, a critical review of peer-reviewed literature on these technologies' effects on animal performance was conducted, as well as their effects on beef food safety. Findings of this research were then used as inputs into a breakeven model to illustrate the effects of these production systems relative to conventional production. And finally, these inputs were used to forecast the effect of removing these technologies from beef production and its impact on natural resource requirements. Modern beef production has achieved remarkable strides in the efficient use of natural resources to provide a safe and nutritious beef product over the last 30 years.

Résumé

Les systèmes modernes de production de bœuf ont grandement évolué depuis les dernières 30 années tant au niveau du nombre de ranchs et de parcs d'engraissement que des technologies utilisées. Des données se rapportant aux entrées et sorties importantes de la production de bœuf ont été recueillies en 1975 au pic du nombre de bovins de boucherie et comparées aux données de 2008. La plupart des changements dans les 30 dernières années se situent au niveau du développement et de la mise en application des technologies pour la production de bœuf. L'industrie du bœuf a significativement réduit son empreinte environnementale au niveau des terres requises et du nombre d'animaux utilisés tout en augmentant sa production. L'un des changements dans les 30 dernières années dans la production de bœuf a été l'émergence de la production naturelle et biologique du bœuf. Ces systèmes de production ne permettent pas l'utilisation de plusieurs technologies utilisées dans la production conventionnelle du bœuf et la discussion de ces technologies semble un élément directeur dans la production de bœuf que l'on envisage pour le futur. Par conséquent, une revue critique de la littérature scientifique avec comité de lecture concernant l'effet de ces technologies sur la performance animale de même que sur leurs effets sur l'innocuité du bœuf a été menée. Les résultats de cette revue ont été utilisés comme entrées dans un modèle de rentabilité pour illustrer les effets de ces systèmes de production par rapport aux productions conventionnelles. Finalement, ces entrées ont été utilisées pour prédire les conséquences du retrait de ces technologies de la production de bœuf et son impact sur les besoins en ressources naturelles. La production moderne de bœuf a permis des avancées remarquables dans l'utilisation efficace des ressources naturelles afin de fournir des produits du bœuf sécuritaires et nutritifs depuis les dernières 30 années.

The Last 30+ Years

US beef cattle numbers peaked in 1975, just prior to the liquidation of the national beef herd which resulted in the highest per capita beef consumption year on record in 1976 of 83.2 lb (37.8 kg) per person. Thirty years is a relatively short period of time, but the beef industry has been transformed significantly in this short period. In this time there has been a rapid transition from small, 100 head or less family feedyards to large, 10,000+ head multi-owner feedyards. We have seen the widespread adoption of increasingly refined implant and vaccination technologies with the addition of a wider array of injectable and feed-grade antimicrobials. There have also been large advances in farming methods and seed varieties that have resulted in increasingly larger yields of grains and forage. All of this has translated into a rapid increase in the efficiency of beef cattle production in the U.S. in a short amount of time.

Since 1975, commercial cattle slaughter has decreased by 16% while total beef production has increased by 10%, compared to 2008. This was achieved by adding 190 lb (86.4 kg) of carcass weight, which increased

carcass yield by 24%. Heifers have experienced a larger increase in carcass weight than steers over the same period (28% vs 20%, respectively). The nation's cow and replacement heifer inventory has decreased by 30% since 1975, translating into a tighter cattle supply. There are 600,000 fewer farms utilizing 166.1 million fewer acres in 2008 than in 1975, constituting a 15% reduction that is roughly equal to an area the size of Texas that has been taken out of agriculture production. Beef cow operations are 48% fewer and milk cow operations are 85% fewer than in 1975. However, corn production increased by 52%, corn yield per acre increased by 44%, and corn silage per acre increased by 37%, with only a 13% increase of acres dedicated to corn production.

The theme of agriculture for the past 30 years has been maximizing production through efficiency in order to lessen the amount of inputs required. This has greatly decreased the number and quantity of natural resources used to raise beef cattle. This is truly something to take great pride in. The beef industry and agriculture in general have been world leaders in natural resource conservation, well before there were policies and position statements about becoming "green". Now there is a push within agriculture to institute production systems that are "more green" or "sustainable" that "go back to the way it should be".

Organic and Natural Beef Production

Despite recent economic difficulties, the organic and natural food production segments have continued to see increased demand in the US. Conventional beef production systems use technologies prohibited under the National Organic Program's rules for organic beef production.[8] Recently announced USDA regulations for natural beef production prohibit the use of growth-promoting hormones and the use of antimicrobials. However, the new rule does allow the use of ionophores for the control of coccidiosis.[15] Until recently there was no standard definition of "natural beef production", which made it difficult to compare one "natural" beef production system to another. Peer-reviewed research comparing performance effects of natural beef production directly to conventional beef production is sparse.[2,4,10] A meta-analysis method was used because it provides a method of examining existing literature critically and in a quantitative manor, accounting for within- and between-trial variance, in order to provide an overall estimate of effect based on existing data. Data were gathered to evaluate the performance and health effects of technologies used in conventional beef production. Technologies we examined were steroid implants, monensin, tylosin, endectocides, and metaphylaxis with any antimicrobial on arrival and their effects on the performance and health of beef-breed feedlot cattle. We also examined tylosin inclusion in the diet and its effect on liver abscess production due to field reports of increased prevalence of liver abscess lesions in natural-fed cattle.

Data Gathering & Analysis

The question was: What is the difference in average daily gain (ADG), gain-to-feed (G:F), dry matter intake (DMI), morbidity, mortality, and liver abscess risks in feedlot cattle with and without pharmaceutical technologies in North America? Using a systematic search technique, manuscripts were identified through PubMed and Commonwealth Agricultural Bureau (CAB) electronic databases from February 2008 thru April 2008. The Intervet/Schering-Plough Animal Health (Kenilworth, NJ) and Texas Tech University North American TBA Implant Database[13] was also used to identify studies utilizing steroid implants due to very little peer-reviewed data. All the data used from this site was referenced directly from the cited publication and subjected to the same critical review as the peer-reviewed sourced manuscripts. Only data from studies using a single implant treatment (i.e. no re-implant) with a contemporary non-implanted control group were considered to control for as much variability between studies as possible. The implant data was further subgrouped into implant studies utilizing heifers and studies utilizing steers to attempt to mitigate the amount of variability in the data sets due to sex.

For inclusion in the analysis, studies were only retained if the study was conducted in North America, used randomization in allocation of treatment group, used beef-breed animals, and contained an untreated control group. Data were then extracted from the studies that met the inclusion criteria. Data for the performance effects and a measure of the standard error (SE) for each measure were recorded along with mortality, morbidity, presence of liver abscess, description of experimental unit, number of experimental units, and sex of cattle.

Forest plots were used to visually assess whether the effect of the technology on the performance effects (ADG, DMI, G:F) was uniform across studies. For this graphic approach, the production outcome and standard deviations were used to calculate the differences between groups, and these data used for the forest plot. Studies to the right of the null value indicate a positive value and studies to the left have a negative value. Technologies were considered to be uniform when 50% of the point estimates (boxes) on the forest plot were to one side of the null effect line.

For the continuous outcomes ADG, DMI, and G:F, technologies considered to display a uniform response compared to negative controls were analyzed using general linear mixed models in Proc Mixed of SAS (SAS Inst. Inc., Cary, NC). In brief, each model of continuous

outcome variables (ADG, DMI, G:F) contained one fixed effect (steroid implants, monensin, tylosin, endectocides, metaphylaxis), a random intercept effect for each study, and a repeated effect to incorporate a within-study variance for each study.[16] The model-adjusted means and SE for the performance effects, when statistically significant, were used to derive a 95% confidence interval for the summary effect and were incorporated into a standardized feedlot breakeven model.

The metaphylaxis morbidity and mortality data and the tylosin liver abscess incidence data were analyzed with generalized linear mixed models with a logit link and binomial distribution using the Glimmix procedure of SAS (SAS Inst. Inc., Cary, NC). Metaphylaxis was included in the model statement as a fixed effect, and when significant, model-adjusted estimates were transformed from the logit form to generate the estimated probability of treatment or death if receiving metaphylaxis, or having liver abscesses if consuming tylosin, respectively. Therefore, the estimated probability represents a cumulative incidence or risk of these adverse health events occurring at some point during each trial.

Breakeven Model

A standardized feedlot breakeven model similar to many commonly used by feedlot consultants and managers to assess the economics of feeding a pen of cattle with user defined inputs was used.[12] The economic model assumptions are listed in Table 1. Based on an average of the ADG and G:F reported by Berthiamune,[2] Fernandez and Woodward,[4] and Sawyer,[10] we used an ADG of 2.87 lb/day (1.3 kg) and a G:F of 0.14 to predict the breakevens for "natural" raised calves. The estimated differences for ADG and G:F calculated in the meta-analysis for implant technology use were then used in the model to arrive at the estimated economic difference between natural and implanted feeder cattle. And finally, the model was used to predict feeding the "natural" calf an organic diet. For the organic breakeven analysis, the days-on-feed was increased by 20 days[4] and the organic feed costs were multiplied by 1.5[14] to simulate the feedlot performance and feed cost differences of feeding organic cattle.

Table 1. The economic model assumptions used for the common breakeven inputs. Dollar amounts are in US dollars.

Economic model assumptions	Assumption
In BW (lb)	550
Laid in price ($/lb)	1.10
Vaccination cost ($/hd)	2.50
Dewormer cost ($/hd)	1.60
Feed cost ($/ton)	171.00
Days-on-feed	210
Yardage/day ($/hd/d)	0.30
Interest rate	6.50%
Out BW (lb)	1252
Shrink	4.00%
Fat cattle price/lb	0.96

Meta-analysis and Breakeven Results

A total of 14,311 citations were identified by the initial electronic search. After critical review of the relevant manuscripts that met the inclusion criteria, 91 treatment-to-control comparisons were identified from 51 manuscripts. The three most frequent reasons studies were excluded were failure to include an untreated control group, failure to report variation of the outcome either as a standard deviation or SE, and failure to use or explicitly state the use of randomization to allocate animals to treatment groups.

Based on visual assessment of the forest plots, use of endectocides (figure not shown), steroid implants (Figures 1 and 2), monensin (figure not shown), and metaphylaxis (Figure 3) showed a performance advantage for treated cattle relative to the cattle in negative control groups. Tylosin studies did not show a consistent advantage in treated cattle relative to control cattle with respect to ADG, G:F, and DMI. An insufficient number of studies met the inclusion criteria to conduct a meta-analysis comparing endectocides, monensin or tylosin. Therefore, a summary effect measure was only calculated for metaphylaxis and implant data sets.

Meta-analysis and Breakeven

Average daily gain in feeder cattle receiving metaphylaxis using a variety of antibiotics on arrival was 0.24 lb (0.1 kg)/day higher (95% CI = 0.22 to 0.29, $P < 0.01$) relative to cattle that did not receive metaphylaxis on arrival (Table 2). Use of implants in heifers was associated with increased ADG by 0.18 lb (0.08 kg)/day compared to non-implanted controls (95% CI = 0.02 to 0.33, $P = 0.09$). Use of implants in heifers was not associated with differences in G:F ($P = 0.14$) or DMI ($P = 0.44$). Use of implants in steers was associated with 0.55 lb (0.25 kg)/day greater ADG (95% CI = 0.50 to 0.60, $P < 0.01$) and 1.17 lb (0.53 kg)/day greater DMI (95% CI = 0.99 to 1.34, $P < 0.01$) relative to non-implanted control steers. Use of implants was also associated with increased G:F in steers relative to non-implanted steers by 0.02 lb (0.009 kg) (0.17 vs. 0.15 lb [0.077 vs 0.068 kg], implanted vs. controls, 95% CI = 0.018 to 0.022, $P < 0.01$).

Point estimates of differences in ADG and G:F for implanted and non-implanted steers were incorporated into the breakeven model. The model suggests that

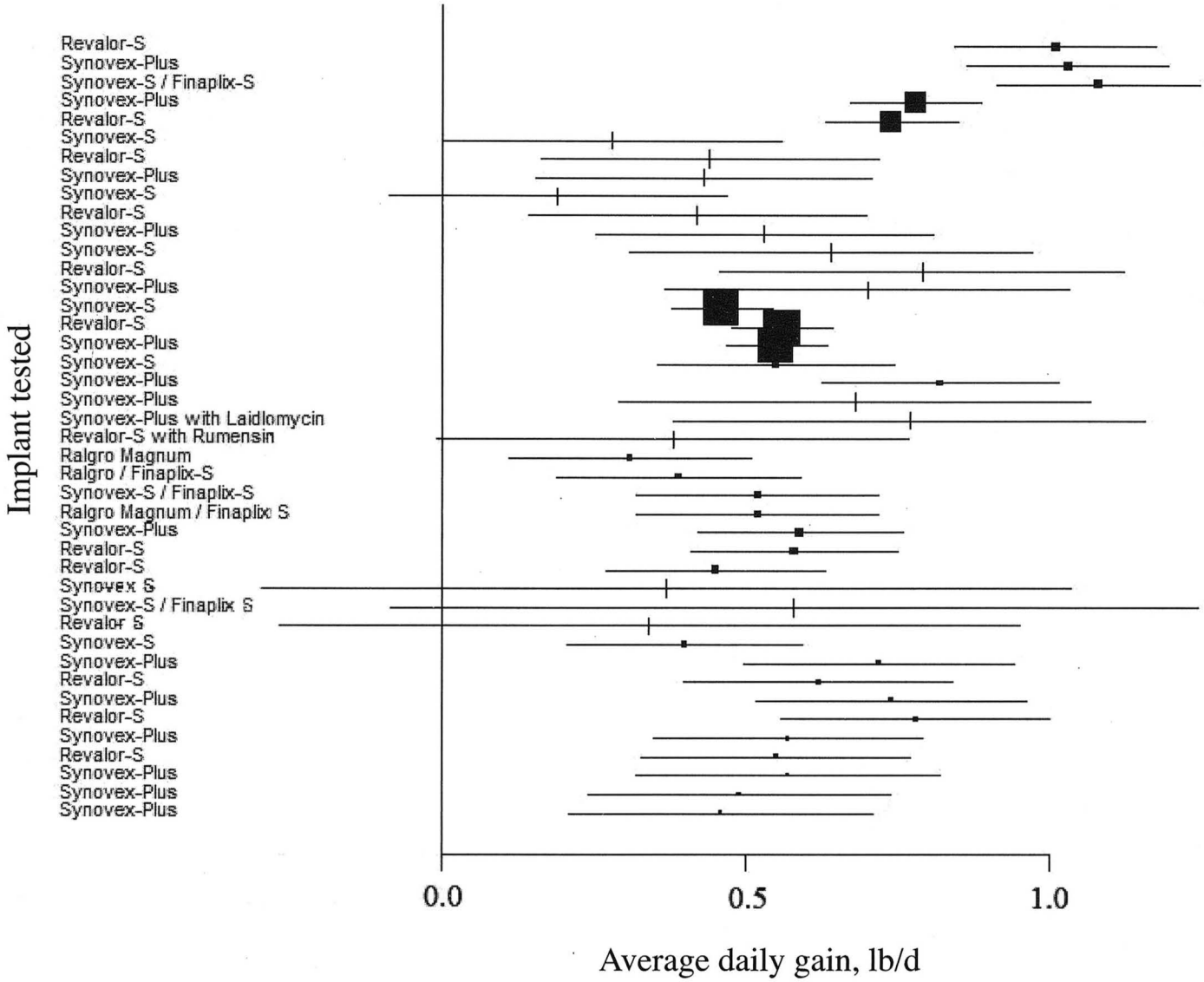

Figure 1. Forest plot of implanted steers and corresponding ADG: overall mean effect and 95% confidence interval listed by the single implant used in the study.

implanted steers were associated with $65 per head lower cost of production than non-implanted steers fed similar diets. Also, implanted steers fed a non-organic diet had a $284 per head lower cost of production than non-implanted cattle fed an organic diet. This model is not accounting for any premiums received for carcass or production method, or any costs associated with morbidity or mortality. For each 10% increase in the price of organic feed, the breakeven estimate increased approximately $54/head. The simulations did not incorporate morbidity and mortality effects.

Morbidity, Mortality, and Liver Abscesses

For cattle that received metaphylaxis upon arrival to the feedyard, morbidity was estimated at 29% (95% CI = 21.2% to 38.58%) compared to 55% (95% CI = 44.46% to 65.14%) in the cattle that did not receive metaphylaxis ($P < 0.01$; Figure 4). For cattle receiving metaphylaxis, mortality was estimated to be 1.8% (95% CI = 1.05% to 3.12%) compared to 3.8% (95% CI = 2.30% to 6.50%) for cattle not receiving metaphylaxis ($P < 0.01$; Figure 4). Cattle not fed a ration containing tylosin had an estimated 30% (95% CI = 18.62% to 44.77%) risk of having liver abscesses compared to 8% (95% CI = 4.43% to 14.07%) in cattle consuming tylosin ($P < 0.01$; Figure 4).

Summary of Pharmaceutical Technologies

The results comparing implanted cattle to non-implanted suggest there is approximately a 17% improvement in ADG and a 9% improvement in G:F, which

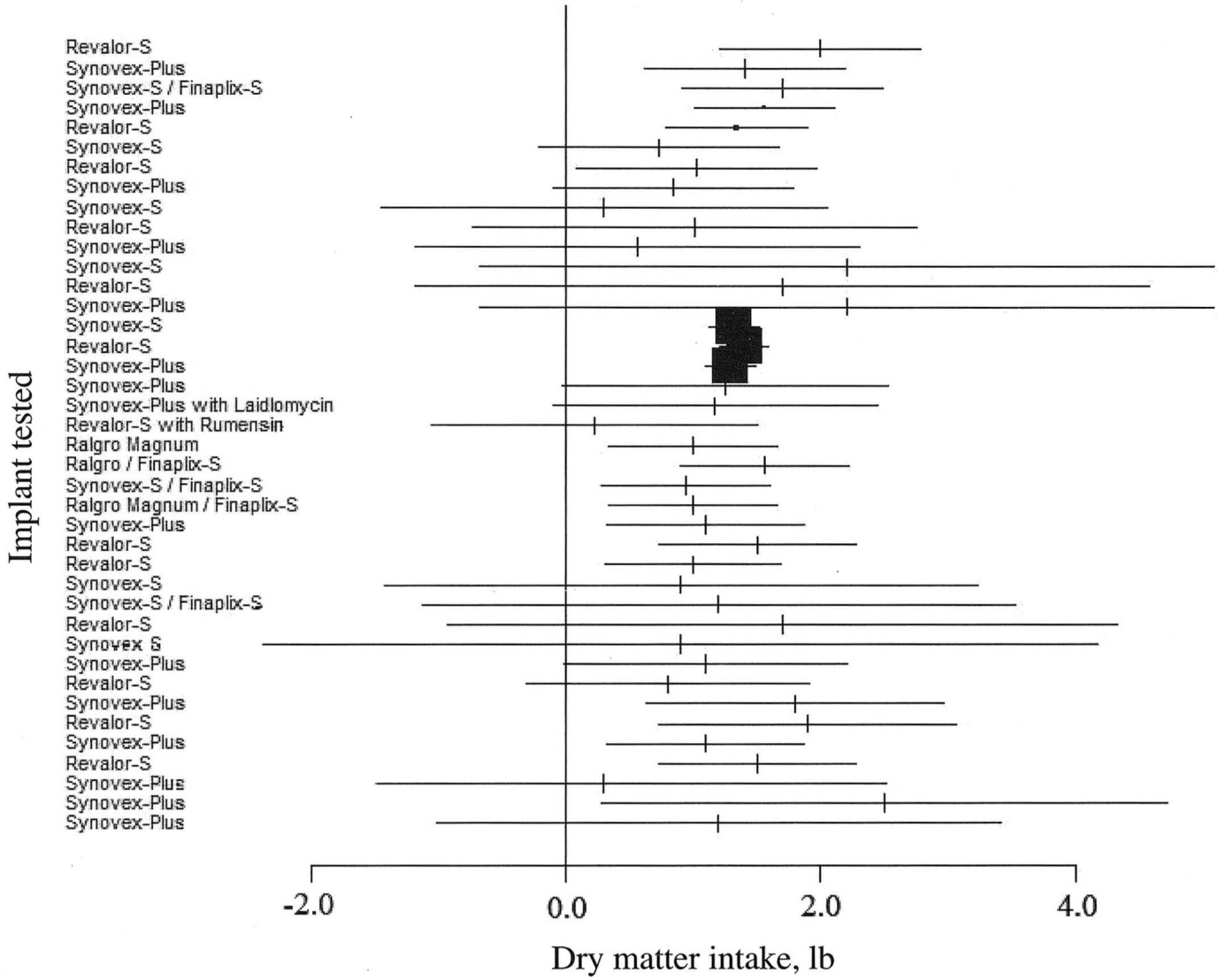

Figure 2. Forest plot of implanted steers and corresponding DMI: overall mean effect and 95% confidence interval listed by the single implant used in the study.

is in agreement with other reports of expected implant performance.[1,3,9] Results of the breakeven model provide an accurate indication of the premiums necessary to offset increased costs of producing beef in alternative systems compared to producing beef in conventional beef production systems. The use of metaphylaxis on arrival resulted in an estimated 53% reduction in subsequent morbidity treatments and an estimated 27% reduction in mortality losses compared to cattle not receiving metaphylaxis.

Feeding tylosin to feedlot cattle reduced the liver abscess risk from 30% to 8% in the studies examined. This study did not look at the severity of liver abscesses and relate it back to subsequent performance, which might explain why there was no significant difference in ADG between tylosin treatment groups. In their review of liver abscesses, Nagaraja and Lechtenburg[7] reported significant variation in the performance effects of abscessed livers and stated that it was likely a function of severity. The small or mild liver abscesses likely have less of a negative impact on performance than do larger or more severe abscesses.

Use of pharmaceutical technologies, coupled with improved genetic selection technology, has increased the amount of beef produced per animal and has produced that beef more efficiently and economically.[6] The benefits of using these modern technologies are not just limited to the three performance indicators that we measured, but could include control of bloat, coccidiosis, and external parasites, which are achieved with use of technologies. Moreover, this study did not address several other technologies that are commonly used to control reproductive

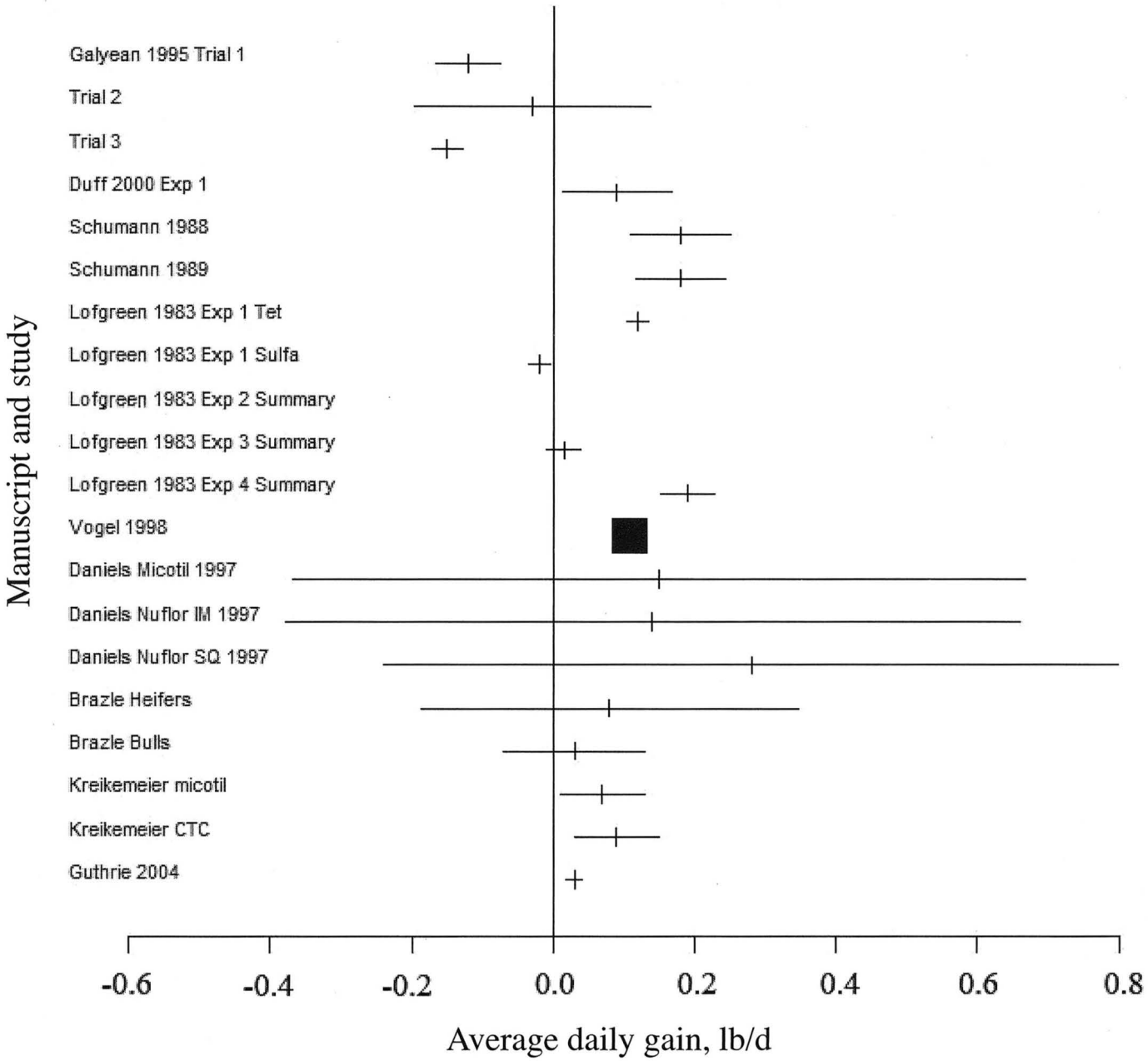

Figure 3. Forest plot of metaphylaxis use and corresponding ADG: overall mean effect and 95% confidence interval listed by manuscript and study.

cycling in heifers or increase the amount of hot carcass weight (HCW) in the final period of feeding. As technologies are integrated into conventional feeding systems, their effects on economical and biological efficiencies in beef cattle production, as well as on environmental and animal welfare issues, will need to be examined.

Based on a study of just 54 cattle, Fernandez and Woodward[4] reported that a 39% greater selling price would be required to compensate for the performance reductions incurred with organic beef production, as compared to conventionally produced steers. Our simulated breakevens indicate that a $0.23/lb ($0.10/kg) live BW premium is required for an "organically-raised" animal to generate the equivalent net return compared to a "conventionally-raised" animal. Fernandez and Woodward[4] also reported a 0.03 decrease in G:F and a 16% decrease in ADG in "organically-raised" steers compared with "conventionally-fed" steers. Our study also found that the difference in feed cost makes up the majority of the cost difference between the two systems. In a 40-head study, Berthiaume *et al*[2] found that non-implanted cattle had a 16% reduction in HCW,

Table 2. Differences in least squares means (95% CI) for implants and metaphylaxis from significant results in the mixed model.

Technology	ADG (lb/day)	Improved G:F	DMI (lb/day)
Metaphylaxis	0.24 (0.22-0.29)***	---	---
Implanted heifers	0.18 (0.02-0.33)†	0.02 ‡	---
Implanted steers	0.55 (0.50-0.60)***	0.04 (0.018-0.022)***	1.17 (0.99-1.34)***

‡P= 0.14
†P<0.10
***P<0.001

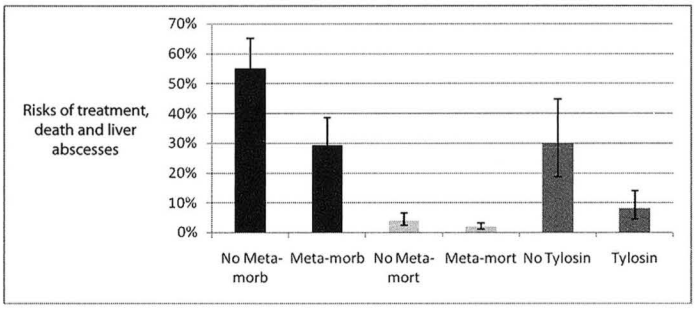

Figure 4. Risks of treatment and death of cattle receiving and not receiving metaphylaxis and risks for liver abscesses in cattle receiving and not receiving tylosin.

a 31% reduction in quality grade, and would require a 15% greater premium over implanted cattle to remain equivalent. Our simulated breakeven model suggests that a "naturally" raised steer will have to generate at least a $0.05/lb ($0.02/kg) live BW premium to generate a return equivalent to a conventionally raised steer. Sawyer *et al*[10] also demonstrated similar results in a 64-steer study. Lawrence and Ibarburu[5,6] also used meta-analysis to examine the effects of removal of all pharmaceutical technologies from all segments of beef production. There were no statements as to article selection or the process for examining the evidentiary value of the articles. Nonetheless, they estimated the effect of removal of pharmaceutical technologies from the feedlot phase of production to be $155/head, which is similar to the estimate calculated from this study. Our model only examined the effects of a single implant and used only the difference due to that single implant in the analysis. Lawrence and Ibarburu attributed $71 of the $155/head difference to implants, whereas this analysis estimated $65/head benefit. There are likely benefits in ADG and G:F for multiple implant programs that could explain the remainder of the difference between our estimates and those of Lawrence and Ibarburu.

We found that many studies have shifted away from including untreated controls in an effort to compare one technology to another. As the natural and organic industries continue to grow, it will be important to evaluate the effect of various technologies on beef production efficiency. It is also important that the beef industry conducts further field trials comparing natural or organic systems directly to conventional systems. It is equally important to report the data more thoroughly by reporting measures of variation between treatment groups and between measured outcomes, and accurately describing methods used for blinding, as we had to exclude several studies for these reasons. A detailed summary of this trial with a complete list of references included in the analysis has been published previously.[17]

The Future

What would be the impact of removing the technologies we use today and moving to an all natural beef production system? The data to use for an accurate prediction is limited at best. Using the data obtained for the performance (ADG, G:F, and DMI) difference due to implants in steers, we calculated the additional number of cattle required to keep equal production levels and the related additional natural resource requirements. A number of simple assumptions were entered into this model and are summarized in Table 3. These assumptions are likely "best case" scenarios

Table 3. Assumptions used in predicting the future resource needs of beef cattle production.

Input	Assumption
Days-on-feed	+30 days
Meat production	Equal to 2008 level
Calving percentage	95%
Calf death loss	1%
Heifer replacement	15%
Corn yield	175 bushels/acre
Hay yield	1.5 ton/acre
Soybean yield	55 bushels/acre
Grazing land	20 acres/cow

and should be interpreted with caution, as they likely lead to underestimation of what would result. Based on the assumptions, there would need to be at least 1.6 million additional beef cows entered into production that would take an additional 34.8 million acres that are not in production today to support the cows and feed their calves. This land would have to come from somewhere, and that "somewhere" would most likely be our national parks and grasslands. With such a large focus currently being placed on how "green" one industry is or isn't, beef production sure appears to be making remarkable environmental progress.

The future is unknown. But it does appear that if we as a beef industry and agriculture in general do not get involved and tell our story, especially the last 30 years' worth of progress, someone else will, and we may not like it.

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