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Finishing Cattle in All-Natural and Conventional Production Systems

Zachary K. Smith[1*], Peter T. Anderson[2], Bradley J. Johnson[3]

[1]Department of Animal Science, South Dakota State University, Brookings, SD, USA
[2]Midwest PMS, LLC, Firestone, CO, USA
[3]Department of Animal and Food Sciences, Texas Tech University, Lubbock, TX, USA
Email: *zachary.smith@sdstate.edu

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Abstract

Beef cattle producers in the North America have a variety of production and marketing options and must choose the best production system for their situation. This review describes considerations involved in choosing between feeding cattle conventionally versus feeding them in programs that prohibit the use of certain technologies. Data from peer-reviewed journals, extension publications, nutritional consultants, governmental organizations, and feed companies were used to construct this review. Most cattle in North America are fed in conventional production systems. Conventional beef production systems typically use steroidal implants, ionophores, and beta-adrenergic agonists to improve animal productivity; as well as feed grade and injectable antimicrobials to control, treat or prevent disease and improve animal health. These technologies have been shown to lower the cost of production, allowing for beef to be competitive in the global protein market. Some consumers have expressed a preference for beef produced without these technologies. These "All-natural" (AN) cattle may bring a premium price in the market. The economic impact of differing productions systems can be described in relation to 1) cost of production, 2) operating costs of the feedlot, 3) price paid for feeder calves, and 4) price received for fed cattle. Conventional production provides the most favorable outcome for factors 1, 2, and 3, while AN production provides the most favorable outcome for item 4. There are also industry wide and societal aspects related to differing beef production systems related to health and safety of beef, land use, and cost of production allowing for a greater share of the global protein market. Technologies used in conventional production are critical tools to North American beef production. Differences in efficiencies between each type of non-conventional production systems must be re-captured in added premiums when cattle are marketed and sold. Premiums for AN cattle are enticing, but the true differences in the cost of production between the AN and conventional cattle must be evaluated in order for a producer to make the correct decision for their operation.

Keywords

All-Natural, Beef, Beta-Adrenergic Agonist, Conventional, Ionophore, Production Systems, Steroidal Implant

1. Introduction

Beef cattle producers must choose the best production system for their situation. Conventional production systems use steroidal implants, ionophores, and beta-adrenergic agonists to improve animal productivity; feed grade and injectable antimicrobials are also used to control, treat or prevent disease and improve animal health. Conventional systems also allow feeding of animal by-products and genetically modified feedstuffs, which may not be allowed in some natural programs and are never allowed in organic cattle feeding systems. These management differences between conventional and "All-natural" (AN) lower the cost of production in favor of conventional production. However, some consumers have expressed a preference for beef produced without these technologies.

Since the European Union banned the use of growth promoting compounds in animals intended for human consumption in 1989 [1] [2], and increased demand domestically, the natural-fed segment of the US beef market has grown. The definition of the term "natural" within the context of beef production channels is more ambiguous than the definition of "organic" or non-hormone treated cattle (NHTC). According to the US Department of Agriculture-Food Safety Inspection Service (USDA-FSIS), all fresh beef qualifies to carry a "natural" label, because fresh beef is only minimally processed, and contains no artificial ingredients, or chemical preservatives. Thus, understanding what is meant in reference to "natural" requires some clarification.

Organic and NHTC beef production are clearly defined. The Agricultural Marketing Service of the USDA (USDA-AMS) has an organic certification that requires cattle be managed under a prescribed protocol from the last third of gestation throughout the entire life of the animal [3]. Additionally, the USDA-NHTC program has clearly defined management practices and is verified through USDA audits.

Unlike the USDA-Organic and NHTC programs, AN beef programs are not USDA certified. These AN programs are primarily managed by branded beef marketing groups and involve a third-party audit of participating entities. Thus, for cattle fed in AN programs the conditions of each individual marketing program dictate the types of feed, feed additives, as well as other pharmaceutical and growth technologies that can be used during production. Most AN programs fit "Never Ever 3" (NE3) specifications, meaning that the cattle have 1) never received exogenous hormones, 2) have never received antibiotics (injectable or in feed), and 3) never been fed animal by-products. For a period of time, NE3 specifications were audited by the USDA, but the agency ceased that oversight in November of 2015. Nonetheless, NE3 is a commonly used term among natural beef programs and is often closely aligned with their specifications. Throughout this paper, anything that is not produced conventionally or organically will be referred to as either AN or NHTC. For these examples, AN will match NE3 specifications, NHTC will allow use of any technology except certain growth promotants (**Table 1**). The objective of this review is to compare technology effects on production systems used in North American beef production to allow for individual organizations to determine which production system is best for their customers.

2. Animal Performance and Economic Considerations

At an individual organization level, the economics of production may differ among conventional, AN, NHTC, and organic systems. These differences are driven by system effects on: 1) cost of production, 2) operating cost of the feedlot, 3) price paid for feeder cattle and 4) price received for fed cattle.

Cost of production. The largest difference in cost of production between programs is the use, or non use of growth promoting technologies. For more than 60 years, US beef cattle producers have safely used various types of growth-enhancing technologies (GETs) to increase carcass leanness, increase average daily gain (ADG), improve feed to gain ratio (F:G), and alter dry matter intake (DMI). Steroidal implants and beta-adrenergic agonists are two technologies that increase production efficiency by enhancing animal growth [4] [5] [6]. Previously diethylstilbestrol was routinely used in US beef production; in other parts of the world, the beta-adrenergic agonist clenbuterol has been used. However, use of these compounds has been discontinued due to human safety concerns. Use of approved technologies is proven to be safe for cattle and consumers of beef, and routinely provides a positive return on investment to the producer [4] [7] [8].

Table 1. Use of technologies by beef marketing program.

Technology	Organic	All-Natural	Non-Hormone Treated Cattle	Conventional
Steroidal implants	Prohibited	Restricted or not used	Not allowed	Commonly used
Estrus suppression (melengestrol acetate)	Prohibited	Restricted or not used	Not allowed	Commonly used
Beta-adrenergic agonists	Prohibited	Restricted or not used	Not allowed	Commonly used
Injectable antimicrobials	Prohibited	Prohibited	Allowed	Used as necessary
Feed grade antimicrobials	Prohibited	Prohibited	Allowed	Used as necessary
Anthelmintics	Prohibited	Allowed	Allowed	Used as necessary
Coccidiostats	Prohibited	Restricted or not used	Allowed	Used as necessary
Feeding of animal by-products	Prohibited	Restricted or not used	Allowed	Allowed
Conventionally produced feeds	Prohibited	Allowed	Allowed	Commonly used

When considering alternative systems that disallow use of these technologies, it is important to understand potential consequences regarding production losses. Lean, Thompson and Dunshea [5] used a meta-analysis to indicate that the use of zilpaterol hydrochloride can increase hot carcass weight by 15 kg, final BW by 8 kg, and ADG by 0.15 kg/d and that ractopamine hydrochloride can increase hot carcass weight by 7.3 kg, final BW by 6.5 kg, and ADG by 0.24 kg/d. In another meta-analysis conducted by Reinhardt and Wagner [4] estrogen based, steroidal implants increased HCW by 21.4 kg and ADG by 0.27 kg/d. Thus, when a producer chooses to utilize a GET, improvements in treated cattle over non-treated cattle are typically in the range of 10% to 30% for ADG and 5% to 20% for F:G [4] [5] [6] [8].

The use of steroidal implants can alter apparent dietary net energy (NE) for gain values by increasing feed consumption above that required for maintenance and by lessening the caloric content of growth. Steroidal implants alter mature body weight (BW), in turn altering the caloric content of growth at a given BW relative to a non-implanted animal. Beta-adrenergic agonists lessen the caloric content of growth by acting as either partitioning or repartitioning agents which enhance lean tissue deposition and lessen fat deposition. The use of ionophores can alter apparent dietary NEg values by improving ruminal fermentation and in some cases increased intake such as seen with laidlomycin propionate versus monensin sodium [9]. Thus, differences in cost of production and apparent dietary NE values due to differences in gain that were attributed to the pharmaceutical growth technologies can be assessed.

Differences in cost of production can also be assessed related to differences in feed cost of gain. In an implant study by Smith, Thompson, Hutcheson, Nichols and Johnson [10] steers were administered no implant, a 200 mg trenbolone acetate (TBA) and 40 mg estradiol-17β (E_2) implant (Revalor-XS) 213 d prior to harvest, or a 200 mg TBA and 20 mg E_2 implant (Revalor-200) 143 d prior to harvest (**Table 2**). Monensin sodium and tylosin phosphate were included in the diet. Results from these implant regimens provide insight to what might be expected when cattle are administered no steroidal implant, are given an implant that may be administered for this production window, and an implant administered to steers who became disqualified for an AN feeding program approximately 70 d into the 200 d feeding period. The use of implants decreased ($P \leq 0.05$) the feed cost of gain approximately 9.5% compared to non-implanted steers.

Maxwell *et al.* (2015) compared AN to conventional production systems. Conventional management approaches including a steroidal implant, ionophore and feed grade antimicrobial along with the use and non-use of zilpaterol HCl were compared to an AN feeding program. In the AN vs conventional systems comparison, feeding monensin sodium, tylosin phosphate, and administering a steroidal implant decreased the feed cost of gain approximately 21.0% compared to the AN steers (**Table 3**). In the same study, when zilpaterol HCl was fed to another group of conventionally managed steers, there was an approximately 25.0% decrease in feed cost of gain compared to AN steers.

Table 2. Feed cost of gain ($/0.454kg) in steers not implanted or implanted and fed for 213 d.[1]

	Treatment[2]			
Item	NI	Revalor-XS	Revalor-200	SEM
Feed Cost of Gain, $/0.454kg				
$150.00, 907-kg DM	0.50[a]	0.46[b]	0.46[b]	0.009
$200.00, 907-kg DM	0.67[a]	0.61[b]	0.61[b]	0.012
$250.00, 907-kg DM	0.84[a]	0.76[b]	0.77[b]	0.015
$300.00, 907-kg DM	1.01[a]	0.91[b]	0.92[b]	0.184

[1]Adapted from [10]. [2]Treatments included: no implant (NI), 200 mg TBA and 40 mg E_2 administered at trial initiation (Revalor-XS) or 200 mg TBA and 20 mg E_2 administered on d 70 (Revalor-200). [a,b]Means without a common superscript differ ($P < 0.05$).

Table 3. Feed cost of gain ($/0.454kg) for steers fed All-Natural, Conventional, or Conventional with zilpaterol hydrochloride for an average of 136 d.[1]

	Treatment[2]		
Item	NAT	CONV	CONV-Z
Feed Cost of Gain, $/0.454kg			
$150.00, 907-kg DM	0.63	0.49	0.47
$200.00, 907-kg DM	0.83	0.66	0.63
$250.00, 907-kg DM	1.04	0.82	0.78
$300.00, 907-kg DM	1.25	0.99	0.94

[1]Adapted from [33]. [2]Treatments included: all natural (NAT), fed monensin sodium, tylosin phosphate, and administered an anabolic implant under conventional management (CONV), and conventional management + zilpaterol HCl (CONV-Z).

Using raw data from the Thompson, Smith, Corbin, Harper and Johnson [9] study the feed cost of gain was calculated. In this work, cattle were fed four different treatments: no ionophore or feed grade antimicrobial, fed laidlomycin propionate and chlortetracycline for 151 d, fed laidlomycin propionate and chlortetracycline for 119 d and offered ractopamine HCl [300 mg/head (hd)/d] for the final 32 of the 151 d feeding period, or fed monensin sodium and tylosin phosphate throughout the 151 d study and ractopamine HCl [300 mg/hd/d] was fed for the final 32 d (**Table 4**). All steers in the study were implanted with a 100 mg TBA and 14 mg estradiol benzoate implant at study initiation. Feeding laidlomycin propionate and chlortetracycline decreased ($P \leq 0.05$) the feed cost of gain by approximately 6.0% compared to the control diet. In the same study, feeding laidlomycin propionate and chlortetracycline for 119 d and ractopamine HCl the final 32 d, decreased ($P \leq 0.05$) the feed cost of gain by nearly 6.0% compared to the control diet. Feeding monensin sodium and tylosin phosphate throughout the study and ractopamine HCl the final 32 d, decreased ($P \leq 0.05$) the feed cost of gain by almost 6.0% compared to the control diet. These examples used a dry diet cost of $250.00/907-kg DM, and are only intended as a reference as to what can be expected in regard to technologies that alter F:G, if feed pharmaceutical additives or growth technologies were used, diet cost could increase. Specific ingredient standards and common generally recognized as safe compounds (*i.e.* direct fed microbial, yeast cultures, and organic trace minerals) used in some non-conventional production systems could also increase diet cost versus conventional. Therefore, one must input their own ration cost when comparing systems within their production constraints and level of management. It is important to note that if apparent energy value a diet is increased when pharmaceutical compounds are used, the cost of GET (*i.e.* ractopamine HCl) addition to the diet must be less than the apparent improvement in dietary energy value. If this is the case, the use of pharmaceutical and growth technologies decrease the cost of each unit of energy that is used during production and also decrease the feed cost of gain.

To illustrate a direct comparison of AN and conventional production systems, closeout summaries from two large commercial feedyards were obtained (Table 5). These two yards typically place cattle of similar genetic merit into their AN/NHTC programs and their conventional feeding program. The differences in ADG between cattle in the differing programs was 24.61% and 11.70% for steers and heifers between AN and conventional across both feedlots, respectively.

Table 4. Feed cost of gain ($/0.454kg) for steers fed differing feed additives for 151 d.[1]

	Treatment[2]				
Item	CON	LP	LPRH	MT	SEM
Feed Cost of Gain, $/0.454kg					
$150.00, 907-kg DM	0.43[a]	0.40[b]	0.40[b]	0.40[b]	0.005
$200.00, 907-kg DM	0.57[a]	0.54[b]	0.54[b]	0.54[b]	0.007
$250.00, 907-kg DM	0.71[a]	0.67[b]	0.67[b]	0.67[b]	0.008
$300.00, 907-kg DM	0.86[a]	0.81[b]	0.81[b]	0.81[b]	0.010

[1]Adapted from [9]. [2]Treatments included: no ionophore or antimicrobial (CON), fed laidlomycin propionate (12.1 mg/kg DM) and chlortetracycline (350 mg/hd/d) for 151 d (LP), fed laidlomycin propionate (12.1 mg/kg DM) and chlortetracycline (350 mg/hd/d) for 119 d and ractopamine HCl (300 mg/hd/d) for the final 32 d (LPRH), and fed monensin sodium (36.4 mg/kg DM) and tylosin phosphate (12.1 mg/kg DM) for 119 d and ractopamine HCl (300 mg/hd/d) was also included for final 32 d (MT). [a,b]Means without a common superscript differ ($P < 0.05$).

Table 5. Summary of performance from two commercial feedyards that place cattle of equal genetic merit into their AN and conventional feeding programs.

	Steers, Yard A		Heifers, Yard A		Steers, Yard B		Heifers, Yard B	
Item	Natural	Conv.[1]	Natural	Conv.	Natural	Conv.	Natural	Conv.
Initial BW[2], kg	385	367	360	359	371	367	350	328
Out BW, kg	571	639	575	599	609	689	572	594
DOF[3]	133	152	150	160	173	202	163	184
ADG[4], kg	1.24	1.66	1.20	1.42	1.31	1.51	1.29	1.36
DMI[5], kg	9.64	9.86	9.45	9.35	10.17	9.55	9.88	8.81
F:G[6]	7.75	5.93	7.86	6.58	7.79	6.34	7.69	6.5
Death loss, %	2.63	1.92	4.75	1.75	1.71	1.75	7.76	2.35

[1]Conv. = Conventional management. [2]BW = body weight. [3]DOF = days on feed. [4]ADG = average daily gain. [5]DMI = dry matter intake. [6]F:G = DMI/ADG.

When foregoing use of implants during the finishing phase, a producer gives up 10% to 30% responses in ADG, but performance loss is not equal across gender groups. Herschler, Edwards, Olmsted, Sheldon, Hale, Preston, Bartle and Montgomery [11] reported that steers and intact heifers administered an implant that contained 200 mg of TBA and 28 mg of estradiol benzoate had improved ADG by 20.9% and 10.5% compared to non-implanted controls for steers and intact heifers, respectively. Pritchard and Rust [12] summarized six studies representing 1468 heifers in total [13]-[18]. In their pooled analysis, steroidal implants increased ADG by 10.5% and 15.7% compared to non-implanted controls for intact and ovariectomized heifers, respectively. Differing responses between steers, intact heifers, and ovariectomized heifers when steroidal implants are used is most likely due to differences in endogenous estradiol-17β production between steers, intact heifers, and ovariectomized heifers [19] [20].

Sex differences in ADG responses to a steroidal implant suggest that heifers might be better suited for feeding in AN programs than steers. This is most likely due to a lower response curve (*i.e.* improvement over a non-use animal), that in turn can reduce the penalty for not capturing the potential of the technology. Heifers are inherently more expensive to feed as indicated by purchase price discrimination [21] [22]. However, a marginal improvement in gain or efficiency is more valuable in a heifer than a steer. The marginal improvement in gain or efficiency coupled with the magnitude differential must be considered in order to determine if heifers are better suited for AN production compared to steers.

The question of genetic capability is significant because of substantial differences inherent in the feeder cattle population. Often, cattle being fed in AN, NHTC, and USDA-Organic programs are cattle that represent the surest guarantee of traceability available to producers. It is not uncommon for these AN cattle to have ADG similar to conventionally raised animals. Initially, one might be pleased with the performance of their AN cattle compared to their conventional cattle if ADG is similar between both groups; however, this is not a fair comparison. If an implanted steer gains 1.63 kg/d, he would likely have gained approximately 1.36 kg/d without the steroidal implant (*i.e.* a 20% response in ADG due to the steroidal implant). Likewise, an AN steer that gains 1.59 kg/d without the use of a steroidal implant would be expected to gain 1.91 kg/d (*i.e.* a 20% increase in ADG) if administered a steroidal implant which has been demonstrated by others [23]. Thus, feeding in an AN or NHTC program may limit the return on investment for the animal with the best genetics available. When all things are considered (*i.e.* fallout rate and salvage weight of the fallout animal), economic performance might have been better using the technology on the valuable calf as compared to managing the animal under the guidelines of an AN or similar program.

Substantial variation in the feeder cattle population exists, data in **Table 6** and **Table 7** show the range in value (deads-in) for closed lots of 306 kg heifers and 306 kg steers. These data were obtained from a random subpopulation of all closeouts in recent years for customers of Midwest PMS, based upon sex (heifers

Table 6. Range in value of 306-kg feeder heifers (deads-in).

PHV[1]	Lots	Initial BW[2], kg	Out BW, kg	DOF[3]	ADG[4], kg	DMI[5], kg	F:G[6]	Mortality, %	Value, $/hd	vs the average
550	2	297	540	143	0.61	8.46	14.39	28.81	558.66	−382.79
600	3	306	545	159	0.78	10.53	13.96	20.69	591.65	−349.80
650	5	305	505	177	0.69	7.77	11.44	15.43	637.52	−303.93
700	8	302	541	181	0.96	8.81	9.27	12.38	713.55	−227.90
750	34	303	545	177	1.02	8.50	8.37	11.18	758.50	−182.95
800	71	303	543	177	1.12	8.47	7.63	7.83	803.23	−138.22
850	176	304	542	175	1.22	8.57	7.08	4.81	853.15	−88.30
900	444	304	546	172	1.33	8.78	6.63	2.53	903.64	−37.81
950	833	307	555	168	1.43	8.97	6.27	1.56	951.32	9.87
1000	523	308	573	170	1.53	9.30	6.09	1.10	995.83	54.38
1050	144	309	597	175	1.63	9.72	5.97	0.71	1043.18	101.73
1100	11	311	611	172	1.72	9.73	5.63	0.71	1087.54	146.09
1150	3	310	618	196	1.56	7.83	4.95	0.00	1138.82	197.37
Total	2257	307	559	171	1.41	9.00	6.45	2.30	941.45	0.00

[1]PHV = Per head value; index value (by 50.00 $/head increments) of a dollar per head breakeven purchase price. [2]BW = body weight. [3]DOF = days on feed. [4]ADG = average daily gain. [5]DMI = dry matter intake. [6]F:G = DMI/ADG.

Table 7. Range in value of 306-kg feeder steers (deads-in).

PHV[1]	Lots	Initial BW[2], kg	Out BW, kg	DOF[3]	ADG[4], kg	DMI[5], kg	F:G[6]	Mortality, %	Value, $/hd	vs the average
600	2	300	626	196	0.87	9.06	10.73	22.92	612.32	−396.79
650	3	310	564	67	0.67	7.67	11.60	25.24	653.51	−355.60
700	7	306	540	194	0.77	7.79	10.19	14.80	692.63	−316.48
750	15	307	558	180	0.98	8.47	8.61	13.18	749.42	−259.69
800	31	306	566	184	1.09	8.62	7.94	10.28	798.10	−211.01
850	63	305	580	189	1.22	8.73	7.17	7.51	855.37	−153.74
900	128	306	584	193	1.31	8.83	6.78	4.57	903.43	−105.68
950	306	305	593	193	1.39	8.89	6.41	3.56	952.01	−57.10
1000	474	306	609	194	1.49	9.08	6.10	2.49	1000.38	−8.73
1050	536	307	629	198	1.59	9.36	5.92	1.63	1049.32	40.21
1100	288	308	652	202	1.68	9.75	5.81	1.09	1095.67	86.56
1150	74	308	679	212	1.73	9.90	5.74	0.86	1139.45	130.34
1200	13	308	722	236	1.74	9.98	5.75	0.66	1198.34	189.23
1250	3	308	691	212	1.80	8.74	4.86	0.27	1252.21	243.10
Total	1943	307	618	196	1.51	9.22	6.19	2.74	1009.11	0.00

[1]PHV = Per head value; index value (by 50.00 $/head increments) of a dollar per head breakeven purchase price. [2]BW = body weight. [3]DOF = days on feed. [4]ADG = average daily gain. [5]DMI = dry matter intake. [6]F:G = DMI/ADG.

and steers) and placement weight (initial BW of 295 to 317 kg). These data can provide a benchmark for what the actual feeder cattle population in the US entails. An understanding the value the current feeder cattle population is capable of generating can prove useful when making decisions related to differing production programs. The value for each lot was calculated using a standardized feed and sale price. Out weight was used along with the standard sale price to calculate revenue. After revenue was calculated, cost of production (*i.e.* feed consumed, medicine and processing costs, and other miscellaneous costs) was subtracted in order to calculate a breakeven purchase value of the entire lot as feeders. This value was then divided by number of hd placed to calculate a per hd value (PHV). The PHV is the total amount that could have been paid for each animal in the lot at placement in order to breakeven. The data are indexed in $50/PHV increments to generate the rows of mean data presented in **Table 6** and **Table 7**.

Given the price and cost assumptions, the average value of all 306 kg feeder heifers was $941.45/hd and a $139.47/45.4kg purchase breakeven (**Table 6**). The two lowest value heifer lots had PHV of $558.66/hd and $85.42/45.4kg purchase breakeven as feeders. The two low value lots ($550 PHV) had mean ADG of 0.61 kg/d, F:G of 14.39, and 28.81% mortality and were worth $382.79/hd less as feeders than the average. Alternatively, there were three exceptional lots ($1150 PHV) that had average PHV of $1138.82/hd and a purchase breakeven of $166.49/45.4kg as feeders. These three exceptional lots of heifers had mean ADG of 1.57 kg/d, F:G of 4.95, and no mortality. These three $1150 PHV lots of heifers were worth $197.37/hd more than the average as feeders and $580.16/hd more as feeders than the lowest PHV index lots.

It is the same story for 306 kg feeder steers (**Table 7**) except the range in value is even greater at $639.90/hd more as feeders between the lowest and greatest PHV groups. The greatest PHV indexing steer lots had exceptional gain, a heavy market weight, minimal mortality, and they also exhibited outstanding F:G. These higher quality cattle have a higher purchase breakeven as feeders. High value feeder cattle stay alive, eat, and get very large, they also convert feed to gain very efficiently. However, without known and repeated use of a source of cattle, these traits are very difficult to ascertain *a priori* and if this was possible, then realized purchase price would reflect the differential in prices. If these traits were easily identified *a priori* this could mean that a conventional feeder has an opportunity to attempt to purchase these cattle away from the AN feeder without having to be concerned with fallout cattle from the primary market or changes in marketing channel due to seasonal demands.

<u>Operating cost of the feedlot</u>. Operating costs are increased by implementation of an AN program. Compliance costs can be substantial. Most AN programs require specific documentation of how the cattle were managed. This level of documentation is not required for marketing through conventional channels. Labor and equipment required to move fallout cattle represent an added cost.

Cattle fed in the USDA-Organic program are strictly limited to organic feedstuffs and no constituents of the diet may be obtained from another animal. Other AN programs are not typically required to be fed organic feedstuffs and some allow the use of animal by-products in feed. A feedlot that chooses to feed some pens under conventional management and other pens in the same feedlot under management practices that prohibit the use of some feed additives might easily fail to comply with program requirements if all cattle are fed using the same equipment. The analytical assays used to check for drug compliance during auditing are conducted under high pressure liquid chromatography. Most AN programs only require a signed affidavit, however, sensitive analytical procedure can detect traces of drugs in the ppm (mg/kg) to ppb (μg/kg) range. Minimizing cross contamination can become impossible when using the same equipment if there is a "zero-tolerance" policy. Even if there is not a "zero-tolerance" policy, flushing and feed management can become very difficult with the level of surveillance capable using the employed analytical techniques. If the same system cannot be used to feed conventional and AN cattle, the cost of implementing the AN feeding program increases. One opportunity is to exclusively feed AN cattle at a designated facility in the organization, however, this only works for operations with multiple facilities and may not work for all of them. This practice would minimize the risk of being out of compliance, but cost of production increases because of transportation of fallout cattle to their new home.

Another cost that must be considered is the lost economic opportunity for the feedlot, if selling feed is their primary source of revenue. Due to intake stimulation by implants, implanted cattle typically consume 5% to 6% more feed per day than non-implanted cattle of similar weight [4]. In addition, the added weight of implanted cattle further increases feed, as intake per unit BW will likely remain unchanged. For a custom cattle feeder, these NHTC cattle will consume less of the feed that is for sale. Producers who charge feed markup should consider higher margins on feed sold to NHTC cattle to equalize revenue to the feedlot. Chute charges or specific handling charges for dealing with fallout cattle could be considered as well.

Pen size and occupancy is another consideration. In an ideal situation, cattle destined for an AN program would not be co-mingled with cattle from other sources in order to fill a pen. Feedyard profitability is maximized with full pens but that often requires feeding cattle from multiple sources together since the average cow herd size in the US is 43.5 hd [24]. Large pens (*i.e.* greater than 150 hd) may not allow the flexibility required to keep cattle from different sources separated. Keeping cattle sorted by sex and source will help minimize morbidity and is critical to effectively producing cattle destined for an AN program. Smaller capacity pens could prove valuable to the AN cattle feeder allowing for greater flexibility in acquiring single and known source cattle. If smaller capacity pens are not available to the cattle feeder, then comingling of program eligible cattle might need to occur to optimize pen occupancy.

The type of diet that is fed to cattle in various marketing programs should be considered. Cattle in an AN program that prohibits the use of an ionophore and steroidal implants, may be better suited for a moderate energy finishing diet (for example, 58 Mcal NEg [net energy for gain]/45.4kg). This strategy of a lower NEg finisher might be better suited for the AN beef animal because, without the use of a steroidal implant, frame can be grown in this individual by using a lower energy finisher as compared to a 69 Mcal NEg/45.4kg [25] diet in order to generate more BW at harvest if using homegrown or economically purchase roughage sources. Although slowing finishing rate can have significant consequences to inventory turnover and unit cost, because of less dilution of fixed costs, it in turn produces heavier weight cattle at harvest [26]. The latter option produces smaller cattle at maturity [26]. Finally, when feeding a finisher with a higher roughage inclusion, the influence of monensin on meal size and frequency might not be as important compared to feeding a low roughage inclusion, 69 Mcal NEg/45.4kg finisher [25]. The type of diet fed to AN destined cattle should match the available feedstuffs and the management skills of the cattle feeder when use of pharmaceutical and growth technologies are not permitted.

Geographic location is another consideration. Feeding operations in the Midwest and High Plains can be profitable for very different reasons. For example, yards in the High Plains typically have favorable weather and pen conditions, but greater feed costs compared to Midwestern yards. Large yards may have dedicated personnel to manage risk when opting to feed cattle that can qualify for an AN program. Alternatively, Midwestern feeders may have the available profit center in home-grown feedstuffs, are closer to the cattle supply, and can in turn also produce cattle destined for AN programs.

<u>Price paid for feeder cattle.</u> In a summary of auction sales from 1995 to 2005 conducted by King, Salman, Wittum, Odde, Seeger, Grotelueschen, Rogers and Quakenbush [21], the average premium for AN cattle was $2.37/45.4kg. A more recent analysis was conducted by Odde, King, McCabe, Smith, Hill, Rogers and Fike [22], who reported that the premium for AN cattle ranged from $1.02 to $4.04/45.4kg, and AN cattle garnered a statistically greater premium in 7 of the 9 y used in the analysis compared to calves not sold as AN. Another important consideration is what percentage of cattle that were market as AN feeder cattle were actually fed in an AN program? One must consider if these AN eligible feeder cattle garnered a premium at sale time for a set of reasons other than being AN program eligible, if they ultimately entered the conventional beef production channel.

<u>Estimating fallout salvage value.</u> In a conventional production setting, cattle in feedlots have three potential outcomes, the first is shipment to the primary market, the second is realization of an unthrifty animal to a secondary market (commonly referred to as a "railer" market), and the final outcome is death [27]. For cattle fed in an AN program, the additional outcome of a "fallout" due to antimicrobial treatment is a possibility. When an animal in an AN program is

treated with an antibiotic, they typically become ineligible for marketing through that AN program and must be removed. Fallout cattle from an AN program are typically treated, then fed, and marketed as NHTC cattle. For NHTC cattle to fall out of their marketing program, they would likely have to be fed a ration contaminated with a beta-adrenergic agonist or melengestrol acetate, inadvertently administered a steroidal implant, or fed corn contaminated with zearalenone.

While there is a premium loss associated with a change in market channel for fallout cattle, these fallout cattle can subsequently have conventional production technologies applied, and there cost of production might be decreased to an unknown degree. However, there is an expected performance loss in any animal that required treatment in the production process. The absolute effect on production is a function of the relative morbidity rate between AN and conventional programs, and the subsequent performance of fallout cattle in the conventional program in order to accurately estimate production cost differentials. If one had direct comparisons of morbidity on a similar class of cattle fed in AN or conventional program, one could determine what system actually leads to increased morbidity between systems. It seems plausible that not using therapeutic would result in increased morbid cattle. Having this information that is dependent upon management systems would allow for more accurate determination of morbidity benchmarks and needed premiums at the time of marketing. Regardless of the fate of these fallout animals, these fallout cattle must be considered in the cost of production to determine what the true differences are in cost of production.

Economic losses associated with fallout cattle can be substantial. The response to application of GET's in fallout animals is unknown and warrants further research if we intended to move away from conventional production methods. Data to estimate these responses is meaningful for accurate comparison of these systems. The salvage value of the fallout cattle is a function of out BW, conventional market pricing, and the rate of realizers in the cattle population relative to realizer value. The weighted average of these two values is an approximation of salvage value for the fallout animal. In most instances mortality would be attributable to origin making the relationship between fallout rates and salvage value difficult to ascertain.

In an AN program the potential for fallout cattle in calf-feds is considerably greater than for yearling cattle because calves tend to have higher rates of morbidity and treatment. Fallout rate can be as high as 20% to 50% with calves and 5% to 10% with yearling placements in an AN program (T. Milton, personal communication). As transit time and distance increases, animal performance decreases and morbidity increases, even with single-source, ranch raised cattle. Typically, feeder cattle that are eligible for AN programs, whether calves or yearlings, are more expensive than commodity cattle because of the scarcity of program eligible cattle or perceived quality of the cattle. Coupled with purchase premium, the large differences in fallout rate between the two classes of cattle favors purchase of yearlings for natural programs. On the other hand, placing only yearling cattle into AN programs, limits the marketing opportunities at different times of the year. It is important to realize that there is a price differential at which the feeder might prefer calves, yearlings, or be indifferent. The factors mentioned above, among many others, determine the size of this spread and thus the decision.

Price received for fed cattle. The primary economic benefit to production of AN or NHTC cattle is a premium received for the fed cattle. These premiums can range considerably but premiums of $100 to $200 per head are common [28]. Net economics of individual lots of cattle can be evaluated by comparing the potential premium received, compared to additional costs incurred. The price received for the finished beef animal certainly favors AN production. However, depending on price paid for the feeder cattle and whether performance matched expectations, the premium (*i.e.* breakeven) that one needs to receive at the time of marketing is difficult to estimate between the various feeding regions and production systems used in the North America. Producers and organizations that successfully feed AN cattle are likely able to do so because of the known technical efficiencies of the feedyard and on average, the premiums are greater than the differential costs of production. Due to seasonal differences in AN cattle supply and demand, packers do not have to buy cattle at AN premiums if orders have been filled. This adds another layer of complexity.

3. Industry and Societal Considerations

In addition to factors affecting the economic decision of an individual producer, there are industry-wide and societal effects of producing beef using conventional production systems, compared to AN systems.

Health and Safety of Beef. One consideration is the health and safety of the food supply. Any new GET marketed in the US is required to pass a thorough, multi-step scientific review by the US Food and Drug Administration to ensure animal well-being and safety to the human food supply. Use of these compounds must continually be proven safe for human consumption via random testing for residues in edible tissue and potential environmental impacts by way of many independently conducted post-approval environmental impact studies [29] [30] [31]. Health and safety of the beef produced is similar between conventional and AN production systems.

Land Use Considerations. From 1992 to 2012 approximately 12.6 million hectares of US farmland were lost to urbanization [32]. Approximately 4.5 million of the lost hectares were farmland with the most ideal soil conditions, growing seasons, and water availability; allowing for the most intensive production with the smallest environmental impact [32]. Therefore, corn acre usage should also be considered when calculating the overall impact of pharmaceutical technologies and growth technologies. For example, using only steers from **Table 5**, 28.1 million hd of 590 kg cattle (AN) would be required to match the beef output of

25 million hd of 664 kg cattle (conventional). Conventionally produced steers had a 24.3% increase in ADG compared to AN steers in **Table 5**. Initial BW was 378 kg and 153 days on feed for AN and initial BW was 367 kg and 177 days on feed for conventional. The resulting ADG was 1.28 and 1.59 kg/d; with DMI of 9.91 and 9.71 kg. The average F:G for in **Table 5** was 7.77 and 6.14 for the AN and conventional steers, respectively. With an estimated DM inclusion of 65% corn in the finishing diet, assuming the DM of field corn is 85%, and 153 or 177 days on feed, the resulting as-fed corn intake would be 1159 and 1314 kg/hd for the AN and conventional steers, respectively. Total corn consumption for 28.1 million hd of AN steers would be 32.61 billion kg and for 25.0 million hd of conventional reared steers would be 32.84 billion kg, resulting in 0.23 billion kg lesser corn consumption by 3.1 million more hd of AN steers. In this example it requires more land to produce conventional beef, however, reducing the number of calves needed to match similar beef production would reduce the required support population, that in turn might allow for a decline in total land use. Also, we can produce more beef with only minimal increases in planted cropland and a reduced need for nearly 3.1 million feeder steers annually. Assuming that the bushel weight of corn is 25.4 kg, and an average yield of 435 bu/hectare for field corn, then similar levels of beef production can occur with 3.1 million fewer feeder steers and only 19.9 thousand more hectares of corn cropland/yr.

4. Conclusion

Pharmaceutical technologies and growth technologies are critical tools to North American and US beef production and consistently offer a positive return on investment by lowering the cost of production resulting in greater gross revenue. Lower cost of beef production increases the likelihood that consumers from various socio-economic classes can enjoy a wholesome, nutrient dense animal protein. The USDA-FSIS monitors levels of various residues in tissues such as muscle and liver, and the risk for residues in meat from animals raised in conventional systems is minute. Pharmaceutical technologies and growth technologies used by beef producers in conventional production systems increase the efficiency of use of available resources, thus, allowing beef to be more competitive in the global protein market. The differences in cost of production and purchase price for AN, NHTC, and USDA-Organic cattle must be recovered in premiums when the cattle are marketed. Magnitude of the premium is dependent upon fallout rate, salvage animal weight and differing costs incurred due to fallout rate. A higher fallout rate might allow for greater salvage out weight and a lower fallout rate might mean limited salvage weight of all fallout animals if treatment is delayed or withheld for a substantial period of time. The management practices used by successful AN feeding programs must not be ignored. There may very well come a time, where the "tools" beef producers routinely use may not be available. In any period of time, cattle feeding enterprises that understand cattle nutritional management and growth biology better than others, are always in a better position than their competitor.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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