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Lean beef production systems for a growing world population

S. K. Duckett[1], B. M. Koch, and J. G. Andrae

Clemson University, Clemson, SC 29634

Abstract. Anabolic implants are used routinely in beef finishing operations in the USA, with over 95% of all cattle finished for beef production being implanted at least once during the finishing period. In grain based systems anabolic implants increase average daily gain (ADG) by 16 to 20%, equivalent to 0.21 to 0.26 kg/d, over non-implanted controls. Feed efficiency expressed as feed/gain ratio is also improved by 9 to 14% over non-implanted controls. These improvements in feed efficiency reduce feed requirements per unit gain by 0.19 to 0.42 kg. Anabolic implants are one of the most cost effective technologies that can be used to finish beef cattle. Estimates are that the use of this practice, on average, returns $143 (USD) per steer with variability depending on the prices of beef and feed grains. Utilization of two combination (estrogenic and anabolic) implants during the finishing phase can return up to $233 per steer. The elimination of growth-promoting technologies would significantly reduce beef production in those counties where they are used and increase the cattle inventory required to produce equivalent amounts of beef. This would equate to greater requirements of feedstuffs and land area to feed a larger number of cattle, with consequently greater methane output and reduced biological and economic efficiency.

Key words: Beef, Efficiency, Implants, Meat quality

Sistemas de producción de carne de res magra para un mundo de población en crecimiento

Resumen. Los implantes anabólicos (IA) se utilizan habitualmente en los sistemas de acabado estadounidenses con más del 95% de todos los bovinos terminados para la producción de carne siendo implantados al menos una vez durante el periodo de acabado. En sistemas en que la alimentación se basa fundamentalmente en los granos cereales, los IA aumentan la ganancia media diaria por 16 a 20%, equivalente a 0,21 a 0,26 kg/d, con respecto al testigo no implantado. La eficiencia alimentaria, expresada como la proporción alimento/peso ganado, también se mejora con la implantación de un 9 a 14% sobre el testigo. Estas mejoras en eficiencia se traducen en una reducción en la cantidad de alimento requerido por unidad de ganancia de 0.19 a 0.42 kg. Los IA constituyen una de las tecnologías más costo efectivas para uso en el ganado vacuno en sistemas de engorde. Se estima que el uso de IA, en promedio, devuelve $143 (USD) por cada novillo, con variación dependiendo de los precios de la carne y de los granos. La utilización de dos implantes combinados (estrogénico-anabólico) durante la fase de acabado puede devolver hasta $233 por novillo. La eliminación de estas tecnologías que promueven el crecimiento, reduciría significativamente la producción de carne de vacuno en aquellos países donde se utilizan y aumentaría el número de animales requeridos para obtener cantidades equivalentes de carne. Esto equivaldría a mayores cantidades de alimentos y de superficie de tierra necesarios para alimentar a un mayor censo animal y con una mayor generación de metano y menor eficiencia, tanto biológica como económica.

Palabras clave: Calidad de la carne, Carne de vacuno, Eficiencia, Implantes

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[1] Corresponding autor: sducket@clemson.edu

Introduction

Estimates are that by 2050 the world population will reach over 9 billion people (US Census Bureau, 2015). This increase in population coupled with fewer farmers and less land area devoted to agriculture will put pressure on our food production systems. Of these 9 billion people, approximately 2 billion will be children and the remaining 7 billion adults, including a significant increase in the proportion of those over age 60 (Pew Research Center, 2014). The recommended dietary allowance for adults is 0.8 g of protein per kg body weight, which equates to 56 g protein/d for a 70 kg adult. Assuming that in 2050 about 75% of the population will meet their requirement through consumption of high quality protein in animal products, the population will have a daily demand of 347 million kg of protein. Since there are more options in the marketplace than beef, we will assume that the relative percentages of per capita intake of animal products remain similar. The present USA per capita consumption is about 25.7 kg chicken (31%), 25 kg beef (30%), 19 kg pork (23%), 6.5 kg fish and shellfish (8%), 5.7 kg turkey (7%), 0.3 kg lamb, 0.1 kg veal, and 14.6 kg eggs (15%) on a boneless weight basis (USDA-ERS, 2015). Beef contains on average about 22% crude protein (Duckett *et al.*, 2009). Based on average dressing percentages (62%) and lean muscle percentage of carcass (60%) for concentrate finished animals (Duckett *et al.*, 2007), the liveweight of cattle needed to supply the protein requirement would be about 934 million kg daily or 341 billion kg annually for the 2050 adult population. Others have estimated that we would need 106 billion kg of beef or 285 billion kg of live cattle (using similar assumptions as above) based on extrapolations from current meat consumption to feed the 2050 world population (FAO, 2012). Regardless of the assumptions used to estimate protein requirements and beef supply, the world will need to produce more food, more efficiently with less land available for agriculture. How will beef producers meet this challenge?

Beef Production Systems

Currently, the USA produces an estimated 11.7 billion kg of beef annually on a carcass weight basis or 18.9 billion kg of live cattle (NCBA, 2015). World beef production is estimated at 58 billion kg with the top three producers, USA, Brazil and European Union, providing about 50% of total production. In the last 10 years, approximately 3.6 million ha of farm land were lost to metropolitan development just in the United States and this trend of reduced farmland is expected to continue with population expansion (ERS-USDA, 2001). Tilman *et al.* (2011) estimates that about 1 billion ha of land would need to be cleared globally in order to meet 2050 global food demands with requirements for agricultural intensification in developed nations and increased land clearing for agriculture in less developed nations. Therefore, more beef must be produced using fewer animals and less land.

Traditionally in the USA, bull calves are castrated early in life and finished for meat production as steers. Heifer calves that are not retained for breeding purposes are also finished for meat production. Over 95% of steer and heifer calves destined for beef production are finished on high concentrate diets in U. S. feedlots. In contrast, many other countries in the world leave bull calves intact and finish these bulls and heifers not retained for breeding purposes in forage-based finishing programs. It is estimated that in Argentina and Brazil, over 95% of all beef production involves finishing in this way. Although more intensive feedlot systems are being developed in these countries, due to cropping demands for the existing agricultural land, these grain-based systems represent only about 5% of the total beef production at this time. The finishing system used (grain vs. forage) impacts lean meat yields, fat deposition, and fatty acid composition of the meat (Duckett *et al.*, 2007, 2009). Finishing to similar time endpoints in a forage-based program would produce 247 kg of carcass weight; whereas, a grain-finishing program would produce 325 kg (Neel *et al.*, 2007). However, carcass composition is different between the two finishing systems with forage-finishing producing carcasses with more lean meat and less total fat than concentrate-finishing. If lean meat yield is calculated, then the difference between production systems would decrease to about 40 kg less muscle and 48 kg less fat produced per carcass in a forage-finished system (Figure 1).

We can debate whether in the USA grain-based systems are sustainable as cattle are often over-finished in hopes of producing marbling (intra-muscular fat) for higher market prices and then excess subcutaneous fat is trimmed off the carcass where it has little to no value. Currently, the USA average carcass weight for finished steers is 418 kg from a 653 kg live animal (USDA-AMS, 2015).

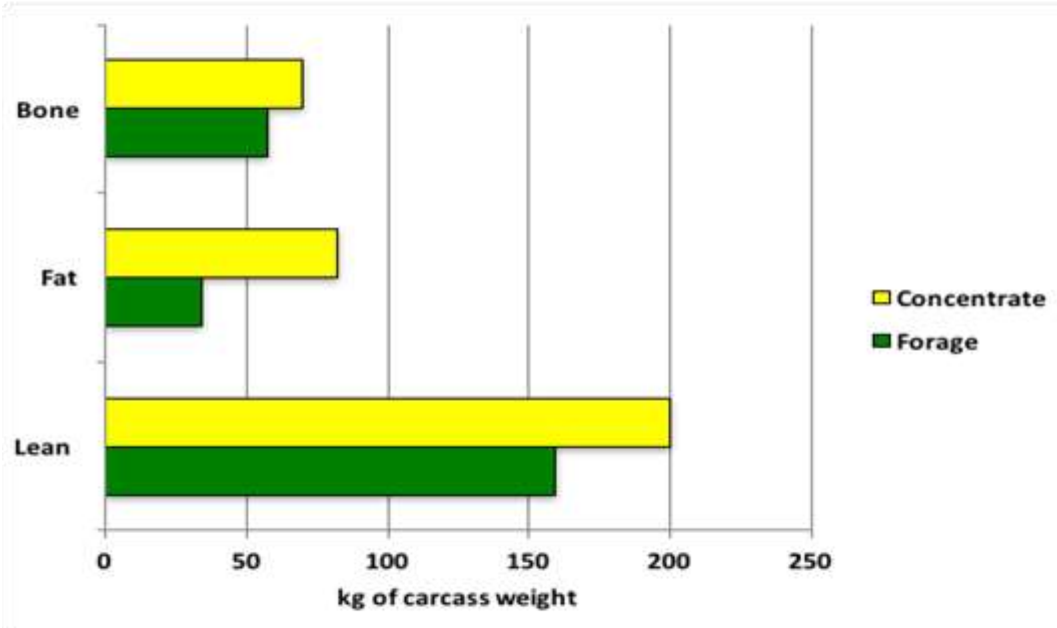

Figure 1. Carcass composition of steers produced under different finishing systems for similar times, comparing high concentrate diets in feedlot (Concentrate) vs. high-quality forage (Forage) (Neel *et al.*, 2007; Duckett *et al.*, 2007).

Carcass weights in the USA have continued to increase due to record high beef prices, low cattle numbers due to drought, recently decreased grain prices, and dilution of fixed costs for slaughter in packing plants. In contrast, most South American countries typically slaughter finished beef cattle in the range of 350-450 kg live weight (Lucerno-Borja *et al.*, 2014; Lobato *et al.*, 2014) or 200-256 kg carcass weight (assuming a 57% dressing percent on forage-finished cattle). In order to meet growing demands for beef, world beef production must: 1) increase the amount of lean beef yield per animal slaughtered, and 2) improve efficiency of production so that it takes fewer resources to produce a unit of beef. One proven method to promote animal growth and efficiency of beef production is to utilize growth-promotant technologies like anabolic implants.

Growth Promotant Technologies

In the USA, over 95% of all beef cattle receive at least one anabolic implant during the finishing phase of beef production (NAHMS, 2000). Anabolic implants are approved for use in feedlot heifers and steers to increase rate of weight gain and improve feed efficiency (FDA, 2013). Over 30 anabolic implant products are approved for use in beef cattle (Duckett and Pratt, 2014). In order to summarize the effects of anabolic implants on finishing beef production, we complied a database and evaluated average responses to implanting for estrogenic (E), combination estrogenic and androgenic (C), and various reimplanting schemes (denoted by "/"). This information is provided in the figures and tables. Anabolic implants increase average daily gain (ADG) by 16 to 20% over the non-implanted controls (Figure 2), which translates to a 0.21 to 0.26 kg/d increase in gain.

Assuming a 200 d finishing period, this equates to an additional 42 to 52 kg of live weight for implanted animals over non-implanted. Gain responses to implanting are greatest for combination implants (+0.25 kg/d ADG) and lower for estrogenic implants (+0.22 kg/d ADG).

Feed efficiency, expressed as feed/gain ratio, is also improved with implanting by 9 to 14% over non-implanted controls (Figure 3). These improvements in feed efficiency translate to a reduction in the feed required per unit gain of 0.19-0.42 kg. The greatest efficiency improvements are observed for combination implants and reimplants (C/C; -0.42 kg/kg) and lowest for estrogenic implants or reimplants (E or E/E; -0.19 kg/kg). When feed costs are high, this improvement in efficiency with implanting is very important for profitability. These improvements are related to both reduced dry matter intake and higher ADG obtained by implanting.

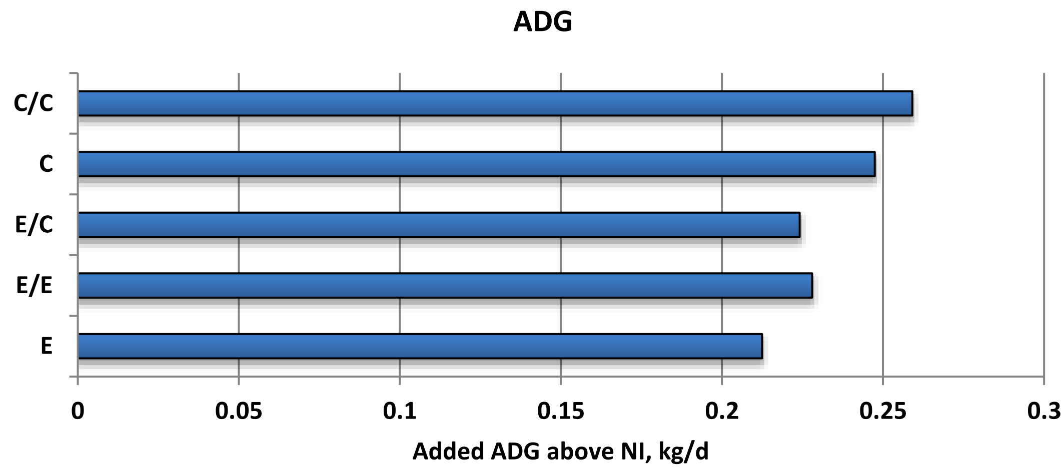

Figure 2. Increase in average daily gain (ADG) by implant type used during the finishing phase (NI = non-implanted control, ADG = 1.30 kg/d; E = estrogenic; E/E = estrogenic with reimplant of estrogenic; E/C = estrogenic with reimplant of combination; C = combination; C/C = combination with reimplant of combination).

Anabolic implants can impact carcass quality and tenderness. Concerns exist about a lower percentage of carcasses grading Choice and increased Warner-Bratzler shear force, an objective measure of meat tenderness. The use of implants during the finishing phase will increase hot carcass weight (HCW), ribeye area (REA), and red meat yields. Anabolic implants will increase HCW by 3-7.5% or about 10-24 kg over non-implanted controls. Reimplants of combination implants (C/C or E/C) give the greatest increases over controls of 21-23.5 kg HCW over non-implanted control. Ribeye area is also increased with implanting by about 3-9%, which translates to increases of 2.2 to 7 cm^2 in REA over non-implanted controls. Most research trials comparing various implant schemes have shown

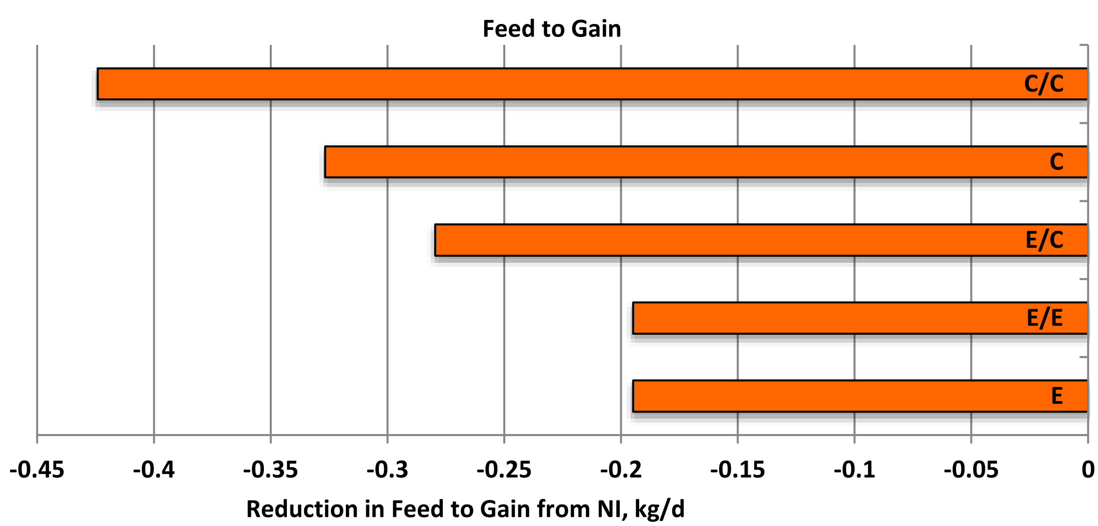

Figure 3. Reduction in feed to gain ratio by implant type used during the finishing phase (NI = non-implanted control, Feed/Gain = 6.91 kg/kg; E = estrogenic; E/E = estrogenic with reimplant of estrogenic; E/C = estrogenic with reimplant of combination; C = combination; C/C = combination with reimplant of combination)

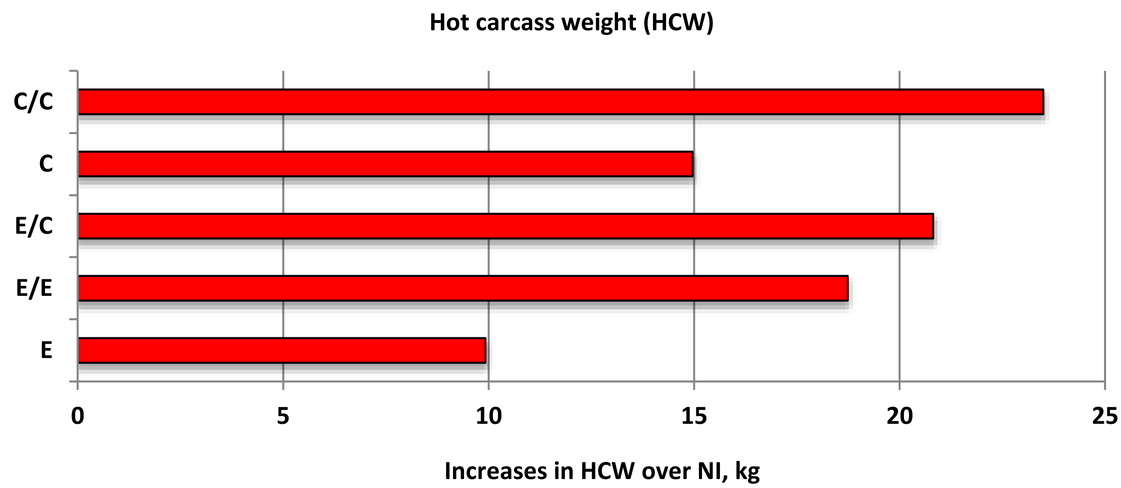

Figure 4. Increase in hot carcass weight (HCW) by implant type used during the finishing phase (NI = non-implanted control, HCW = 315 kg; E = estrogenic; E/E = estrogenic with reimplant of estrogenic; E/C = estrogenic with reimplant of combination; C = combination; C/C = combination with reimplant of combination).

little or no change in subcutaneous fat thickness due to implanting (Duckett *et al.*, 1996; < 10%). Anabolic implants can reduce marbling scores, which may be through a dilution effect with the increase in REA size (Duckett and Andrae, 2001; Duckett *et al.*, 1999). Our research evaluating effects of anabolic implants on lipogenesis show that key lipogenic genes (Elongase 6, fatty acid synthase, stearoyl CoA desaturase, glycerol phosphoacyltransferase) are all down-regulated in adipose tissues from cattle that receive an anabolic growth implant during the finishing phase. Increases in Warner-Bratzler shear force values are observed when postmortem aging is less than 7 d, which may be related to increases in myofibrillar diameter as a result of increased muscle hypertrophy with implanting.

Anabolic implants are one of the most cost effective technologies that can be utilized in beef cattle

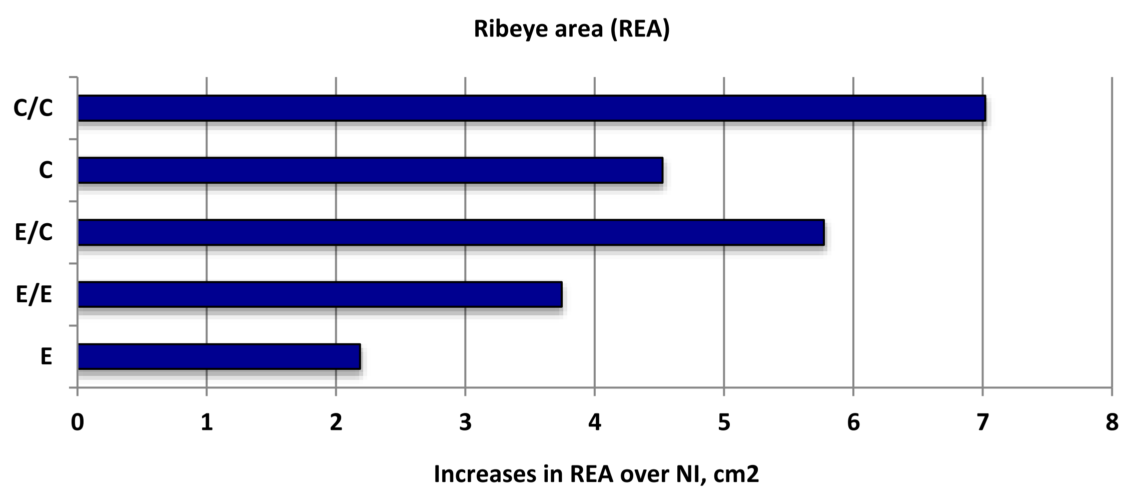

Figure 5. Increase in ribeye area (REA) by implant type used during the finishing phase (NI = non-implanted control, REA = 78 cm^2; E = estrogenic; E/E = estrogenic with reimplant of estrogenic; E/C = estrogenic with reimplant of combination; C = combination; C/C = combination with reimplant of combination).

finishing systems. Estimates are that the use of anabolic implants, on average, returns over $67, $139, and $143 (USD) per animal depending on beef and grain prices (Table 1; Duckett, 1996, Duckett and Pratt, 2014). Utilization of two combination implants during the finishing phase can return from $112, $218, to $233 per head. Others (Beck *et al.* 2014) have also shown that economic improvements from implants also occur in grazing systems with net returns of $30/steer with high value of gain. Berthiaume *et al.* (2006) found that a 16% premium would be needed for forage-fed, non-implanted beef to give the same return as traditional finishing systems, due to lower carcass weights and quality grades.

Capper and Hayes (2012) estimated the environmental and economic impact of growth-promoting technologies utilized in the USA. They concluded that eliminating growth-promoting technologies would significantly reduce beef production or increase the number of cattle required to produce equivalent amounts of beef. This would equate to greater amounts of feedstuffs and land area required to feed an increased number of cattle along with greater methane output and reduced efficiency. If sustainability is truly a concern, then growth-promoting technologies should be utilized and investments made in discovering new technologies to increase beef production for a growing world population. Consumers will likely intensify their demand for lean beef with healthy fatty acid profiles. Many growth-promoting technologies are available to producers that can achieve both; however, consumer acceptance of these products can impact their utilization. This is especially true in European Union and South American countries that prohibit anabolic implants for use in beef production due to concerns over safety. However, if we examine sources of estrogens in common foods of the human diet (Table 2), the concerns over implanted beef are seen to be unfounded, as many other food items and hormone pills contain far greater amounts of estrogenic

Table 1. Monetary benefits from implanting compared to non-implanted controls

Implant type[1]	Return in 1996[2]	Return in 2013[3]	Return in 2015[4]
E	$22.39	$54.02	$54.87
E/E	$40.24	$91.97	$92.25
E/C	$85.05	$168.10	$168.72
C	$76.67	$162.81	$164.69
C/C	$112.53	$218.58	$233.03
Average	$67.38	$139.10	$142.71

[1]E = estrogenic, E/E = estrogenic with a reimplant of estrogenic, E/C = estrogenic with a reimplant of combination, C = combination. C/C = combination with a reimplant of combination.
[2] As reported in Duckett *et al.* (1996) based on $2.37/kg Choice carcass, $2.112/kg Select carcass, and corn grain at $0.132/kg.
[3]As reported in Duckett and Pratt (2014) based on $3.86/kg Choice carcass, $3.78/kg Select carcass, and corn grain at $0.28/kg.
[4]As calculated based on current prices (8/4/15) of $4.84/kg Choice carcass, $4.73/kg Select carcass, and corn grain at $0.1386/kg.

Table 2. Estrogenic activity of various foods sometimes included in the human diet and of two examples of pharmaceutical pills.

Phytoestrogenic or Estrogenic activity	Serving Size	ng/serving
Tofu	85.5 g	40,000,000
Banana-Mango smoothie with soy milk	236.6 g	30,000,000
Soybeans	3 tbsp	28,000,000
Soy milk	236.6 g	12,500,000-25,000,000
Soy burgers	50 g	6,000,000
Peas, lentils, split peas	32-128 g	1,600,000
Beef from pregnant cow	85.5 g	120
Beef from intact bull	85.5 g	3.25
Beef from implanted steer	85.5 g	1.20
Beef from non-implanted steer	85.5 g	0.86
Premarin	1 pill	300,000-1,250,000
Birth control, Ortho-Novum	1 pill	35,000

activity than does beef from implanted steers. Beef from intact bulls, which are finished for meat in countries that do not utilize anabolic implants, also contains 2.7-times more estrogenic activity than that from implanted beef. We must let science be our guide for determining acceptance of growth promoting technologies so that we can feed a growing human population.

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