PEER REVIEWED

Growth promotant implants in suckling calves and stocker cattle: Mode of action, performance response, and practical recommendations

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Abstract

Growth promotant steroid implants increase average daily gain (ADG) by approximately 5% when used in suckling calves, and approximately 14% when used in stocker cattle. Implants used during the suckling or stocker phase do not affect subsequent growing or finishing performance, nor diminish the performance response to implants used during subsequent production phases. Weight added due to the use of implants is, generally speaking, cumulative over the productive life of the animal. In carcasses with a similar degree of marbling, implants do not affect tenderness or eating satisfaction of beef. Dosage of implant should be matched to the weight and age of the animal and to the level of nutrients available; that is, suckling calves should be given a mild implant approved for use in suckling calves, whereas weaned stocker calves grazing a moderate-quality and abundant-quantity forage base should be given a moderate dose implant approved for use in grazing cattle. There is a risk that implants given to replacement heifers at birth may reduce subsequent pregnancy rate; if a single estrogenic implant is provided after 1 to 3 months of age the risk is minimal. A 5% increase in ADG for calves gaining 1.88 lb (0.85 kg)/day for 100 days after implant administration through weaning equates to 9.4 additional pounds (4.26 kg) per calf for sale at weaning, which, based on a $1.82/lb market value for 500 lb (226.80 kg) calves with a 14 cent/lb slide from 500 to 600 pounds (226.80 kg to 272.16 kg), results in an additional $10.40 per calf sold at weaning.

Key words: beef, calves, stockers, implants, growth

Résumé

Les implants stéroïdiens promoteurs de croissance augmentent le gain moyen quotidien (GMQ) par approximativement 5% chez les veaux allaitants et par approximativement 14% chez les veaux en engraissement. Les implants utilisés durant l'allaitement ou l'engraissement n'affectent pas la performance subséquente en croissance et en finition et ne nuit pas à la performance d'autres implants utilisés dans des phases de production subséquentes. Le supplément de poids en réponse aux implants s'accumule, généralement parlant, durant la vie productive de l'animal. Pour des carcasses avec un persillage similaire, les implants n'affectent pas la tendreté ou le niveau de satisfaction du consommateur de bœuf. Le dosage de l'implant devrait correspondre au poids et à l'âge de l'animal et à la quantité d'aliments disponibles. Ainsi, les veaux allaitants devraient recevoir un implant à faible dose approuvé pour son utilisation chez des veaux allaitants. Les veaux sevrés en engraissement ayant accès à du fourrage abondant de qualité moyenne devraient recevoir un implant à dose modérée approuvé pour son utilisation chez des veaux en pâturage. Le taux de gestation chez les taures de remplacement peut diminuer lorsque des implants sont utilisés dès la naissance. Ce risque est minime si un simple implant oestrogénique est utilisé quand la taure a entre 1 et 3 mois d'âge. Une hausse de 5% du GMQ chez des veaux gagnant 1.88 lb (0.85 kg)/jour pendant 100 jours après l'administration de l'implant durant le sevrage se traduit par un gain de 9.4 lb (4.26 kg) de plus par veau à la vente au sevrage. Basé sur une valeur marchande de 1.82$/lb pour des veaux de 500 livres (226.8 kg) avec une valeur ajoutée de 14 sous par livre entre 500 et 600 livres (226.8 et 272.2 kg), cette hausse se traduit par un gain additionnel de 10.40$ par veau vendu au sevrage.

Introduction

Growth promotant steroid implants have been approved for use in beef cattle in the United States since the 1950s.[29] Steroid implants increase the average daily gain (ADG) of stocker calves[17] and of suckling calves.[32] However, a significant proportion of stocker and cow-calf producers choose not to use implants, for a variety of reasons,[3] but the most often cited reason is lack of perceived benefit. This indicates a clear disconnect between the large body of data reporting substantially increased grazing cattle performance with the use of implants and the end user.

The veterinarian is often the first source of technical production information, even if that information does not pertain directly to cattle health,[16] followed by the media, cooperative extension, and product companies. This review is intended to assist the veterinarian in providing useful, practical, technical recommendations to clients with regard to the use of growth promotant steroid implants in suckling calves and stocker cattle.

Mode of Action of Growth Promotant Implants

The active compounds used in growth promotant steroid implants include the estrogenic compounds estradiol 17ß, estradiol benzoate, and zeranol, and the androgenic compounds testosterone and trenbolone acetate. These molecules are included in implants at varying dosages, such that products with a greater dosage of active ingredient are intended to be used in larger animals with greater nutrient availability and greater growth potential. Products have differing label approvals for use in suckling calves, grazing stocker cattle, or for cattle fed in confinement for slaughter (Table 1).

Growth promotant steroid implants cause increased ADG and improved feed conversion in feedlot cattle, resulting in heavier carcass weights and larger ribeye size.[11] Implants improve production efficiency by increasing the efficiency of utilization of absorbed dietary protein.[4,14,39] Plasma urea nitrogen is decreased within 7 days following implant administration,[27,38] indicating increased anabolic activity in cattle by either increased nitrogen utilization for protein synthesis or reduced protein degradation in muscle.

Exogenous estrogens do not directly stimulate growth of muscle cells.[38] Instead, estrogens stimulate growth of tissues indirectly through a number of intermediate processes. Estrogenic compounds stimulate the production and release of somatotropin (growth hormone) from the anterior pituitary,[8,36] insulin-like growth factor I (IGF-1) from the liver,[6] and IGF-1 from within the muscle cell itself.[24,41] Production of IGF-1 in the liver is stimulated both directly by exogenous estrogens, and also indirectly by the elevated somatotropin (which is elevated due to the exogenous estrogen).[6]

One of the many functions of somatotropin is to bind to liver cells to stimulate release of IGF-1.[2] In turn, the primary function of IGF-1 is to bind to target tissues, such as skeletal muscle and bone, stimulating uptake of glucose and amino acids for the synthesis of tissue proteins.[13]

However, because protein synthesis is initiated by transcription of DNA, stimulation of protein synthesis is limited by the total amount of DNA present within a given cell. For the muscle fiber to grow, additional DNA must be provided; this DNA is provided by satellite cells. During normal postnatal growth, muscle hypertrophy (increase in both length and diameter of muscle fibers) occurs because satellite cells located adjacent to the basal lamina of the muscle fiber fuse their cell membrane with that of the muscle cell, and the DNA from the satellite cell is donated to the muscle fiber.[7,22,37] This addition of new DNA to the muscle fiber allows for an increase in genetic material for transcription, resulting in increased protein synthesis. Administration of exogenous estrogenic compounds causes increased production of IGF-1 in the liver and within the muscle cell, which in turn stimulates proliferation of satellite cells, resulting in greater numbers of satellite cells available for fusion.[1]

As animals mature, satellite cells which have not yet fused with the muscle cell may enter a quiescent state in which proliferation ceases,[10] effectively halting muscle hyper-

Table 1. A partial listing of growth promotant steroid implants available in the US along with the active compound or compounds, and the label usage claim.

Trade name	Manufacturer	Active ingredient	Label claim
Ralgro	Merck Animal Health	36 mg zeranol	suckling beef calves, weaned beef calves, growing beef cattle, feedlot steers, feedlot heifers
Synovex-C	Zoetis	100 mg progesterone and 10 mg estradiol benzoate	suckling beef calves up to 400 lb of body weight and steers weighing greater than 400 pounds and fed in confinement for slaughter
Synovex-S	Zoetis	200 mg progesterone and 20 mg estradiol benzoate	steers weighing 400 lb or more
Revalor-G	Merck Animal Health	40 mg of trenbolone acetate and 8 mg estradiol	pasture cattle (slaughter, stocker, and feeder steers and heifers)
Synovex-H	Zoetis	200 mg testosterone propionate and 20 mg estradiol benzoate	heifers weighing 400 lb or more
Compudose	Elanco Animal Health	25.7 mg estradiol	suckling and pastured growing steers; confined steers and heifers
Synovex One	Zoetis	150 mg trenbolone acetate and 21 mg estradiol benzoate	for pasture steers and heifers (slaughter, stocker and feeder)

trophy. Elevated IGF-1 in circulation and within the muscle cell caused by administration of exogenous estradiol results in a delay in quiescence of muscle satellite cells, so that the satellite cells remain in a state of active proliferation during the time in which they would normally become quiescent.[24,41] This delay effectively postpones physiological maturity of the animal, sustaining lean muscle and bone growth which decreases the rate of fat deposition at any point in time post-implant administration.[19,26]

Effects of Implants on Performance of Suckling Calves

An excellent review by Selk[32] indicated that the response in ADG to implanting suckling calves (steers) can be highly variable, ranging from an additional 0.27 lb (0.12 kg)/day in 1 study to a reduction of 0.08 lb (0.036 kg)/day in another; however, all but 2 of the 50 studies summarized indicated a positive ADG response to a single estrogenic implant in suckling calves (Figure 1), and the improvement in ADG vs negative controls across all studies averaged 5.01%. It is not known at exactly what age calves were given the implant, only that it was given during the suckling phase. This variation in response was not clearly attributable to either dosage of implant administered or to basal rate of gain of the negative control calves. On average, a single estrogenic implant given to suckling steer calves resulted in an additional 0.094 lb (0.043 kg)/day ADG vs negative controls. Surprisingly, there were a number of studies (17) in the review that reported little to no benefit (<0.05 lb (0.023kg)/day additional ADG) from implanting suckling calves; however, the majority of studies showed notably improved growth rates for the implanted calves.

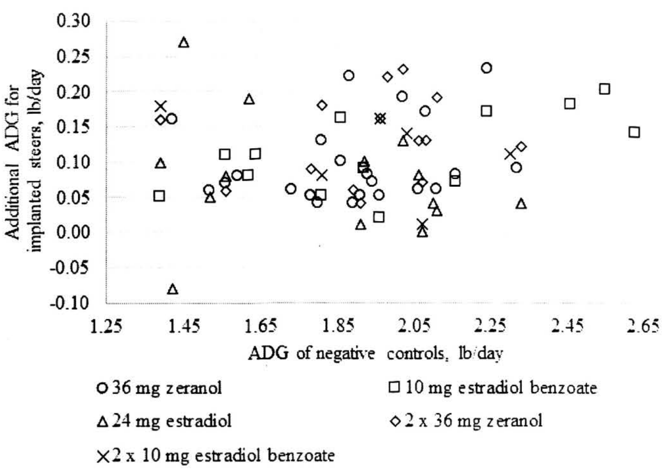

Figure 1. Treatment means from within individual studies for additional ADG (lb/day) for suckling steer calves implanted once prior to weaning with zeranol (36 mg), estradiol benzoate (10 mg plus 100 mg progesterone), or estradiol-17ß (24 mg), or implanted twice with zeranol (36 mg) or estradiol benzoate (10 mg plus 100 mg progesterone) (adapted from Selk, 1997[32]).

There is concern about potential detrimental side-effects of exogenous estrogen on subsequent fertility in heifers. The degree of risk of implanting suckling heifers may be linked to the age at which heifers are implanted[32] (Figure 2). Three studies included in this review examined the effects of providing an implant to heifers at birth, and all 3 studies reported a dramatic decrease in subsequent pregnancy rates (average of -39% vs negative controls). Conversely, if the heifers are implanted at 1 to 3 months of age, or if implants are given at weaning time, there appears to be little, if any, risk to subsequent fertility.[32] Although some studies[9,15] suggest a slight increase in pelvic area at weaning, breeding, and prior to calving in response to growth promoting implants, that potential increase has not resulted in any reduction in calving difficulty (Table 2). Given the lack of clear benefit from the additional weight gained from implanting replacement

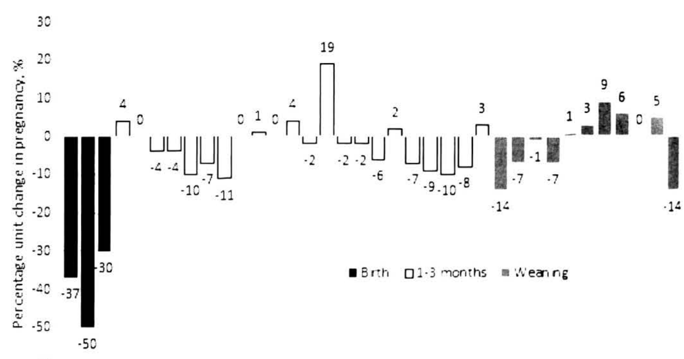

Figure 2. Effects of providing a single estrogenic implant (36 mg zeranol or 10 mg estradiol benzoate plus 100 mg progesterone) to suckling heifer calves either at birth (black bars), at 1 to 3 months of age (white bars), or at or near weaning (gray bars) on percentage unit change in subsequent pregnancy rates (adapted from Selk, 1997[32]).

Table 2. Effects of implanting suckling heifers on subsequent pelvic area and calving difficulty (adapted from Deutscher et al, 1986[9] and Hancock, et al, 1994[15]).

Item	Hancock, et al, 1994	P-value	Deutscher et al, 1986	P-value
Pelvic area at 12 months of age, in^2	+1.2	0.01	---	---
Pelvic area prior to calving, in^2	+1.1	0.01	-0.6	No significant difference
Calving difficulty, %	-3%	No significant difference	----	---
Dystocia score	---		-0.2	No significant difference

heifers, and given the possible negative effects on fertility, it is recommended that implants not be given to heifers which will become breeding females. However, if heifers are likely to be sold as feeder calves after weaning, in light of the substantial increase in weaning weight of implanted heifers, it is recommended that non-replacement heifers be implanted after 1 month of age, with a single implant approved for use in suckling calves (Table 1).

In the past there has been concern that implanting suckling calves may diminish the response of the calves to implants they may receive as stocker or feedlot cattle. A factorial study was conducted in which implants were either provided at birth or at 92-days of age, or given no pre-weaning implant, and the interactive effects of previous implant exposure with effectiveness of the finishing implant was evaluated[40] (Table 3). In calves given an implant at birth, there was no reduction in efficacy of the finishing phase implant; however, in the calves given an implant at day 92 there appeared to be a reduction in efficacy of the finishing implant. This may be due to residual active ingredient remaining from the original implant given on day 92 when the subsequent finishing implant was administered, resulting in an overlap of active ingredient delivered by the 2 sequentially administered implants, and a concomitant excess of exogenous hormone present in the circulation beyond the animals' ability to respond. However, this was not explained in the report.

Mader et al,[21] Pritchard et al,[28] and Mader et al[20] evaluated the effects of suckling calf steroid implant administration on the effectiveness of steroid implants given post-weaning during the growing period (Table 4). These studies showed that performance during the subsequent production phases was not reduced by previous implant status. In general, previous exposure to implants should not be expected to adversely affect perceived efficacy of implants given during the finishing phase, provided the previous implant has not been administered recent to feedlot arrival.

Implanting Stocker Cattle

Sewell[33] reviewed a series of 43 studies conducted across Missouri, which utilized 3,068 stocker calves grazed for an average of 125 days. Implanting stocker calves with 36 mg zeranol resulted in an increase of 14.5% in ADG. An excellent review of the effects of implants on stocker calves was presented by Kuhl,[17] in which the author reported a 13.5% increase in ADG due to implanting stocker steers (implanted with either 20 mg estradiol benzoate plus 200 mg progesterone, 36 mg zeranol, or 8 mg estradiol-17ß plus 40 mg trenbolone acetate) and an average of 13.0% increase in ADG in heifers (implanted with either 36 mg zeranol or 8 mg estradiol-17ß plus 40 mg trenbolone acetate).

Table 3. Effects of previous exposure to suckling implant on subsequent effectiveness of finishing implant (adapted from Ward et al, 1978[40]).

	ADG, lb/d			
	No finishing implant	**Finishing implant**	**Effect of finishing implant**	**Difference based on previous implant**
Implant at birth	2.33	2.75	0.42	---
No implant at birth	2.64	2.88	0.24	0.18
Implant at d 92	2.53	2.68	0.15	---
No implant at d 92	2.42	2.90	0.48	-0.22

Table 4. Effects of implants given to suckling calves on the effectiveness of implants given post-weaning during the growing and finishing phase (adapted from Mader et al, 1994[21] and Pritchard et al, 2015[28]).

	Treatment	**Weaning weight, lb**	**Growing ADG, lb/d**	**Percentage change in post-weaning ADG for calves implanted during the suckling phase vs negative controls**
Pritchard[28] et al, 2008	Control	540	3.46	---
	Suckling implant	563	3.47	+0.3
Mader et al[21], 1994	Control	405	2.46	---
	Suckling implant	433	2.46	0.0
Mader et al, 1985[20] (trial 1)	Control	457	2.97	---
	Suckling implant	464	3.03	+2.0
Mader et al, 1985[20] (trial 2)	Control	480	1.47	---
	Suckling implant	504	1.52	+3.4

The amount of additional gain stimulated by implants is directly proportional to the nutrients available for production (Figure 3). However, regardless of the quantity of nutrients available for growth, implant response in calves in a positive plane of nutrition appears to be consistently between 10 and 20% over basal rate of gain of non-implanted calves. This agrees with the aforementioned means of 13.0,[3] 13.5,[3] and 14.5%[21] increases in ADG for implanted calves vs control calves.

Reimplanting stocker cattle on grass

Reimplanting is a common practice in feedlot cattle. When the total days in the feedlot extends beyond the normal productive delivery span (normally considered to be 120 to 140 days, but this has not been validated or published) of the first implant administered upon arrival, cattle are re-processed and another implant is administered. This practice is uncommon in stocker production, but should be considered if days on pasture extends beyond the productive delivery span of the implant and if nutrition on pasture later in the season will support additional growth. Sewell[34] summarized 3 grazing studies (average of 181 total days on pasture) which examined the benefits of reimplanting on pasture with and without supplementation of protein and energy. In calves supplemented with energy and protein the single-implanted calves gained 1.93 lb (0.88 kg)/day and the reimplanted calves gained 2.03 lb (0.92 kg)/day, an additional 5% improvement in ADG over a single implant. However, in the unsupplemented calves, both single implanted calves and reimplanted calves gained 0.96 lb (0.44 kg)/day for the entire 181 days. Similarly, Smith et al[35] reported no advantage of reimplanting vs giving only a single implant to unsupplemented calves on pasture for 154 days which were gaining under 1.0 lb (0.45 kg)/day. However in calves grazed for 266 days, Rust et al[31] reported that reimplanted calves gained 2.26 lb (1.03 kg)/day compared to 2.16 lb (0.98 kg)/day for single-implanted calves. If nutrient supply on pasture is sufficient to support additional growth, and if the days on pasture extends beyond 150 days, there appears to be a performance advantage to reimplanting calves.

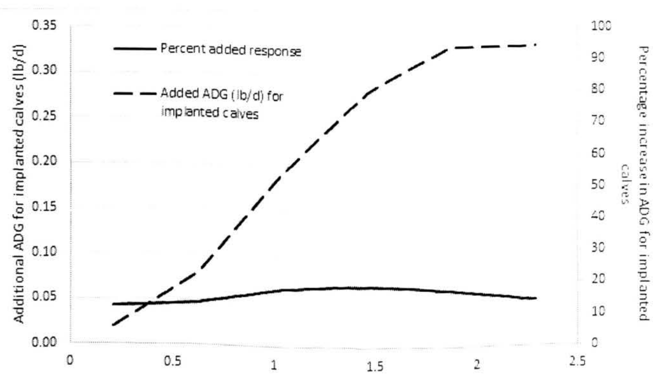

Figure 3. Effects of basal rate of gain on response to providing 36 mg zeranol to stocker calves grazed for 120 days on pasture (adapted from Kuhl, 1997[17]).

Subsequent Feedlot Performance

There is often the question of how an implant given to calves during the suckling or stocker phase may affect subsequent performance and steroid implant response during the feedlot phase. A number of grazing studies have been conducted which evaluated the effects of grazing period implants on both grazing performance as well as feedlot performance and carcass traits (Table 5). It does not appear that grazing implants affect feedlot performance or carcass quality, either positively or negatively; however, carcass weight was statistically greater in 2 of the studies and numerically greater in a third study, suggesting that weight gained while on pasture contributes to final carcass weight, and is not lost over time during the finishing phase. In addition, Platter et al[25] determined that use of a backgrounding implant did not alter consumer perceptions of beef with respect to tenderness, juiciness, flavor, or overall eating satisfaction. Further, Nichols et al[23] determined that in general, when animals are finished to a similar fat-constant endpoint and contain a similar degree of marbling, implants do not affect beef tenderness or consumer eating satisfaction.

Conclusions

Implanting suckling calves and stocker cattle increases ADG by an average of 5% and 14%, respectively. However, the absolute increase in ADG in lb/day in stocker calves is dependent upon the available nutrient supply. If total days on pasture extends beyond 150 days and nutrient supply is abundant, reimplanting stocker calves provides a further increase in grazing performance over a single initial grazing implant. Implants given on pasture do not affect subsequent feedlot performance or carcass quality, but implants given on pasture result in heavier carcass weights after finishing.

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References

1. Allen RE, McAllister PK, Masak KC, Anderson GR. Influence of age on accumulation of alpha-actin in satellite derived myotubes in vitro. *Mech Aging Dev* 1982; 18:89.

2. Beermann DH, DeVol DL. In: Pearson AM, Dutson TR, eds. *Growth regulation in farm animals (advances in meat research).* Vol. 7, Chapter 13. Essex, England: Elsevier Publishing, 1991; 373-426.

Table 5. Effects of implants given to steers during the grazing period on grazing performance and subsequent feedlot ADG and feed conversion.

	Pasture treatment	Rush*	Brandt†	Kuhl‡	Fankhauser¶
Pasture ADG	Control	1.55	1.50	1.69	1.29
	Implanted	1.74	1.71	1.91	1.38
	Percentage change for implanted vs negative controls	+12.2	+14.0	+13.0	+7.0
Feedlot ADG, lb/d	Control	2.89	3.55	3.53	3.64
	Implanted	2.86	3.58	3.57	3.49
	Percentage change for implanted vs negative controls	-1.0	+0.9	+0.3	-4.1
Feedlot feed:gain	Control	7.7	6.06	6.71	5.98
	Implanted	7.6	6.27	6.68	6.28
	Percentage change for implanted vs negative controls	-1.2	+3.5	-0.5	+5.0
Hot carcass weight, lb	Control	---	761^a	786^c	781
	Implanted	---	773^b	800^d	774
	Percentage change for implanted vs negative controls	---	+1.6	+1.8	-0.9
Marbling score	Control	$Small^{50}$	$Small^{10}$	$Small^{19}$	$Slight^{75}$
	Implanted	$Small^{20}$	$Slight^{97}$	$Slight^{97}$	$Slight^{70}$
	Change for implanted vs negative controls	-30	-13	-22	-5

*Adapted from Rush et al, 1989.[30] Pasture-implanted cattle were implanted with either 36 mg zeranol or 20 mg estradiol benzoate plus 200 mg progesterone.

†Adapted from Brandt Jr. et al, 1995.[5] Pasture-implanted cattle were implanted with either 20 mg estradiol benzoate plus 200 mg progesterone.

‡Adapted from Kuhl et al, 1997.[18] Pasture-implanted cattle were implanted with either 8 mg estradiol-17ß plus 40 mg trenbolone acetate, 36 mg zeranol, or 20 mg estradiol benzoate plus 200 mg progesterone.

¶Adapted from Fankhauser et al, 1997.[12] Pasture-implanted cattle were implanted with either 36 mg zeranol or 20 mg estradiol benzoate plus 200 mg progesterone.

[a,b] Means within a column without a common superscript differ ($P < 0.10$)

[c,d] Means within a column without a common superscript differ ($P < 0.13$)

3. Blasi DA, Paisley SI, Sargeant JM, Spire MF. In *Proceedings*. Beef 2000 Stocker: A survey of health, nutrition and management practices and attitudes of the Kansas stocker segment. Beef Stocker Conference, Department of Animal Science and Industry, Kansas State University Experiment Station and Cooperative Extension Service. Food Animal Health and Management Center, College of Veterinary Medicine, 2000.

4. Bouffault JC, Willemart JP. Anabolic activity of trenbolone acetate alone or in association with estrogens, in *Proceedings*. Anabolics in animal production public health aspects, analytic methods and regulation symposium held at OIE, Paris, 1983; 155-179.

5. Brandt Jr. RT, Owensby CE, Milton CT. Effects of grazing system and use of a pasture implant on grazing and finishing performance of steers, in *Proceedings*. Kansas State Range Field Day 1995; 81.

6. Brier BH, Gluckman PD, Bass JJ. The somatotrophic axis in young steers: influence of nutritional status and oestradiol-17 beta on hepatic high- and low-affinity somatotrophic binding sites. *J Endocrinology* 1988; 116-169.

7. Campion DR. The muscle satellite cell: a review. *Int Rev Cytol* 1984; 87:225-251.

8. Copeland KC, DeSouza MM, Gibson PC. Influence of gonadal steroids on rat pituitary somatotropin secretion. *Research Exp Med* 1990; 190:137.

9. Deutscher GH, Zerfoss LL, Clanton DC. Time of zeranol implantation on growth, reproduction and calving of beef heifers. *J Anim Sci* 1986; 62:875-886.

10. Dodson MV, Allen RE. Interaction of multiplication stimulating activity/rat insulin-like growth factor II with skeletal muscle satellite cells during aging. *Mechanisms of Aging and Development* 1987; 39:121-128.

11. Duckett SK, Owens FN, Andrae G. Effects of implants on performance and carcass traits of feedlot steers and heifers, in *Proceedings*. Impact of implants on performance and carcass value of beef cattle. Oklahoma State University, 1997; P-957:63-82.

12. Fankhauser TR, Kuhl GL, Drouillard JS, Simms DD, Stokka GL, Blasi DA. Influence of grazing steers with Ralgro or Synovex-S followed by Synovex Plus or a Ralgro/Synovex Plus reimplant program in the feedlot on pasture/finishing performance and carcass merit. *Kansas State Cattlemen's Day Rep Prog* 1997; 783:38-39.

13. Florini JR. Hormonal control of muscle growth. *Muscle and Nerve* 1987; 10:577-598.

14. Hancock DL, Wagner JF, Anderson DB. Effects of estrogens and androgens on animal growth. In: Pearson AM, Dutson TR, eds. *Growth regulation in farm animals (Advanced Meat Research Vol. 7)*. Essex UK: Elsevier Science, 1991; 255.

15. Hancock RF, Deutscher GH, Nielsen MK, Colburn DJ. Effects of Synovex-C implants on growth rate, pelvic area, reproduction, and calving performance of replacement heifers. *J Anim Sci* 1994; 72:292-299.

16. Jensen KL, English BC, Menard RJ. Livestock farmers' use of animal or herd health information sources. *J Extension* 2009; 47:1FEA7.

17. Kuhl GL. Stocker cattle responses to implants, in *Proceedings*. Impact of implants on performance and carcass value of beef cattle. Oklahoma State University, 1997; P-957:51.

18. Kuhl GL, Milton CT, Stokka GL, Brandt Jr. RT. Comparative performance of grazing steers implanted with Revalor-G, Ralgro, and Synovex-S, and subsequent finishing performance and carcass merit. *J Anim Sci* 1997; 75(sup. 1):233.

19. Loy DD, Harpster HW, Cash EH. Rate, composition, and efficiency of growth in feedlot steers reimplanted with growth stimulants. *J Anim Sci* 1988; 69:920.
20. Mader TL, Clanton DC, Ward JK, Pankaskie DE, Deutscher GH. Effect of pre- and post-weaning zeranol implant on steer calf performance. *J Anim Sci* 1985; 61:546-551.
21. Mader TL, Dahlquist JM, Sindt MH, Stock RA, Klopfenstein TJ. Effect of sequential implanting with Synovex on steer and heifer performance. *J Anim Sci* 1994; 72:1095-1100.
22. Moss FP, Leblond CP. Satellite cells as the source of nuclei in muscles of growing rats. *Anatomical Record* 1971; 170:421–435.
23. Nichols WT, Galyean ML, Thomson DU, Hutcheson JP. Effects of steroid implants on the tenderness of beef. *The Professional Animal Scientist* 2002; 18:202–210.
24. Pampusch MS, Johnson BJ, White ME, Hathaway MR, Dunn JD, Waylan AT, Dayton WR. Time course of changes in growth factor mRNA levels in muscle of steroid implanted and non-implanted steers. *J Anim Sci* 2003; 81:2733-2740.
25. Platter WJ, Tatum JD, Belk KE, Scanga JA, Smith GC. Effects of repetitive use of hormonal implants on beef carcass quality, tenderness, and consumer ratings of beef palatability. *J Anim Sci* 2003; 81:984-996.
26. Preston RL. Possible role of DES on mature size of steers. *J Anim Sci* 1978; 47(Suppl. 1):436.
27. Preston RL. Reduction of plasma urea-N by diethylstilbesterol in ruminants. *Proc Soc Exp Biol Med* 1968; 129:250.
28. Pritchard RH, Taylor AR, Holt SM, Bruns KW, Blalock HM. Time of suckling implant influences on weaning weight, post-weaning performance, and carcass traits in steer calves. *2015 South Dakota State University Beef Cattle Report* 2015-08. Available at: www.sdstate.edu/ars/species/beef/beef-reports/upload/08-Pritchard-Time-of-suckling-implant-influences-on-weaning-weight.pdf. Accessed February 18, 2016.
29. Raun AP, Preston RL. History of diethylstilbestrol use in cattle. *J Anim Sci* 2002. Available at: www.asas.org/Bios/Raunhist.pdf. Accessed February 18, 2016.
30. Rush I, Weichenthal B, VanPelt B. Implants for grazing yearling steers and their effect on feedlot performance. *1989 Nebraska Beef Cattle Rep.* MP 54:33.
31. Rust SR, Gill DR, Nichols CW. Effects of reimplantation for grazing calves. *Oklahoma State University Animal Science Research Report.* 119-121. Available at: http://beefextension.com/research_reports/research_56_94/rr81/rr81_36.pdf. Accessed February 18, 2016.
32. Selk G. Implants for suckling steer and heifer calves and potential replacement heifers, in *Proceedings.* Impact of implants on performance and carcass value of beef cattle. Oklahoma State University, 1997; P-957:40.
33. Sewell HB. Growth Stimulants (Implants). *Missouri Agric Guide.* G2090. University of Missouri, Columbia, Coop Ext Serv, 1990.
34. Sewell HB. The value of reimplants of Ralgro and Synovex for yearling steers on summer pastures, in *Proceedings.* University of Missouri Cattle Backgrounding and Feeding Seminar, 1983; 25.
35. Smith EF, Behnke R, Owensby C. Steer gains on burned and nonburned bluestem pasture and reimplanting with Ralgro at mid-summer. *Cattlemen's Day Report of Progress*, 1981; 79-81. Available at: www.krex.k-state.edu/dspace/handle/2097/7168. Accessed February 18, 2016.
36. Struempler AW, Burroughs W. Stilbestrol feeding and growth hormone stimulation in immature ruminants. *J Anim Sci* 1959; 18:427-436.
37. Swatland HJ. Accumulation of myofiber nuclei in pigs with normal and arrested development. *J Anim Sci* 1977; 44:759-764.
38. Thomson DU. In vitro muscle cell protein synthesis and degradation, nitrogen balance and feedlot response to trenbolone acetate, estradiol and somatotropin in finishing beef steers. PhD Dissertation, Texas Tech University, Lubbock, TX, 1996.
39. VanderWal P, VanWeerdan EJ, Sprietsma JE, Huisman J. Effect of anabolic agents on nitrogen-retention of calves. *J Anim Sci* 1975; 3:986.
40. Ward JK, Klopfenstein TJ, Farlin SD, Petersen L, Schindler GF. Ralgro implants affect performance. *Nebraska Beef Cattle Report.* 1978; EC 78-218.
41. White M, Johnson BJ, Hathaway MR, Dayton WR. Growth factor messenger RNA levels in muscle and liver of steroid implanted and nonimplanted steers. *J Anim Sci* 2003; 81:965-972.