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The efficacy of Norgestomet implants on performance and preventing pregnancy in grazing postpubertal beef heifers

Jamie Hawley, MS[1]; **Jeremy G. Powell**, DVM, PhD[1]; **Elizabeth B. Kegley**, PhD[1]; **Rick W. Rorie**, PhD[1]; **Patrick C. Taube**, MS[2]
[1] Department of Animal Science, University of Arkansas Division of Agriculture, Fayetteville, AR 72701
[2] Zoetis Inc, Kalamazoo, MI 49007
Corresponding author: Dr. Jeremy G. Powell, jerpow@uark.edu

Abstract

A 240-d study was conducted to assess the efficacy of long-acting, erodible implants containing Norgestomet (**NOR**; 11β-methyl-17α-acetoxy-19-norprogesterone) on growth performance and preventing pregnancy in grazing postpubertal beef heifers. Nonpregnant, cyclic crossbred beef heifers (*n* = 240) were stratified by BW (763 ± 7.5 lb [346 ± 3.40 kg]) and assigned to 80 blocks (3 heifers/block). Blocks were allocated randomly to 5 pastures (48 heifers/pasture). Heifers were assigned randomly within block to receive 1 of 3 implants (randomized complete block design) containing 0 (**control**), 100, or 150 mg NOR (d 0). Heifers grazed mixed fescue-bermudagrass pastures with ad libitum access to mineral-vitamin mix. Heifers were exposed to fertile bulls from d 7 to 200 (≥ 1 bull/25 heifers). Bull breeding soundness evaluations were conducted on d 0, 50, 100, and 150. Heifer BW was recorded pretreatment and on d 50, 100, 150, 200, and 240. Pregnancy was diagnosed by ultrasonography on d 50, 100, 150, 200, and 240. Orthogonal contrasts were used to assess the effects of control vs NOR (100 or 150 mg NOR) and dose efficacy (100 vs 150 mg NOR). Control heifers exhibited lower ($P < 0.05$) average daily gain (ADG) when compared to heifers that received 100 or 150 mg NOR (0.84 vs 1.04 and 1.06 lb [0.38 vs 0.47 and 0.48 kg]/d, respectively). Implants did not completely eliminate pregnancy at any NOR dosage. Pregnancy rates were 90.0 (90% CI = [82.9, 94.4]), 8.9 (90% CI = [4.8, 15.8]), and 12.5% (90% CI = [7.5, 20.0]) for control, 100, or 150 mg NOR, respectively. Heifers that received 100 or 150 mg NOR experienced lower ($P < 0.0001$) pregnancy rates compared to control heifers. By d 150, 88.8% (71/80) of control heifers were pregnant, and 90.0% (72/80) were pregnant by d 200. Administration of 100 or 150 mg NOR prevented pregnancy in at least 92.5% of heifers for 200 d. Pregnancy rates of heifers that received 100 or 150 mg NOR were not different ($P = 0.46$). These data suggest that implants containing 100 or 150 mg NOR increased rate of gain and decreased pregnancy rates in grazing postpubertal beef heifers.

Key words: beef heifers, grazing, Norgestomet implant, performance, pregnancy

Résumé

Une étude s'étalant sur 240 jours a été menée afin d'évaluer l'efficacité d'implants à action prolongée érodables contenant du Norgestomet (**NOR**; 11β-méthyl-17α-acé-toxy-19-norprogestérone) sur la performance de croissance et la prévention de la gestation chez des génisses de boucherie post-pubères au pâturage. Des génisses de boucherie de race croisée non-gestantes et cycliques (n=240) ont été stratifiées selon le poids corporel (763 ± 7.5 lb [346 ± 3.40 kg]) et allouées dans 80 blocs (3 génisses par bloc). Les blocs ont été alloués aléatoirement dans 5 pâturages (48 génisses par pâturage). Les génisses recevaient de façon aléatoire à l'intérieur d'un bloc un des trois implants possibles (plan en blocs aléatoires complets) contenant 0 (témoin), 100 ou 150 mg NOR (jour 0). Les génisses broutaient dans un pâturage mixte avec fétuque-bermudagrass et avaient un accès libre à un mélange de minéraux et de vitamines. Les génisses ont été exposées à des taureaux fertiles des jours 7 à 200 (≥ 1 taureaux/25 génisses). Un test de fertilité des taureaux a été fait aux jours 0, 50, 100 et 150. Le poids corporel des génisses a été enregistré avant le traitement et aux jours 50, 100, 150, 200 et 240. La gestation a été diagnostiquée avec l'échographie aux jours 50, 100, 150, 200 et 240. Des contrastes orthogonaux ont été utilisés pour évaluer l'effet des deux implants NOR 100 et 150 par rapport au témoin et l'effet de la dose (100 v. 150 NOR). Le gain moyen quotidien était moins élevé ($P < 0.05$) chez les génisses du groupe témoin que chez les génisses des groupes 100 ou 150 NOR (0.84 v. 1.04 et 1.06 lb [0.38 v. 0.47 et 0.48 kg]/j, respectivement). Les implants n'ont pas complètement prévenu la gestation aux deux doses de NOR. Le taux de gestation était de 90 [IC 90% = (82.9, 94.4)], 8.9 [IC 90% = (4.8, 15.8)] et 12.5% [IC 90% = (7.5, 20.0)] pour les génisses des groupes témoin, 100 NOR et 150 NOR, respectivement. Les génisses qui ont reçu la dose 100 ou 150 mg de NOR avaient un taux de gestation moins élevée ($P < 0.0001$) que

les génisses du groupe témoin. Après 150 jours, 88.8% des génisses (71/80) étaient gestantes dans le groupe témoin et 90% (72/80) l'était après 200 jours. L'administration de 100 ou 150 mg NOR a empêché la gestation chez au moins 92,5% des génisses pendant 200 jours. Le taux de gestation des génisses dans le groupe 100 NOR n'était pas différent de celui dans le groupe 150 NOR ($P = 0.46$). Ces données suggèrent que des implants contenant 100 ou 150 NOR ont permis une augmentation du gain de poids et ont réduit le taux de gestation chez des génisses de boucherie post-pubères au pâturage.

Introduction

Estrus and pregnancy are undesirable in beef heifers destined for the feedlot. A recurrent display of estrus behavior adversely affects productivity[9,21] and has been associated with the occurrence of dark cutters.[24,30] Pregnant heifers exhibit lower average daily gain (ADG) and have reduced feed efficiency,[22,34] and their dressing percentage declines with advancing gestation length.[4,22,24] Accordingly, a method of suppressing estrus and ovulation while increasing heifer productivity is needed.

Ovariectomy requires skilled labor, can lead to unwanted morbidity and mortality, may fail to remove all ovarian tissue, and reduces heifer performance unless implanted with an estrogenic or androgenic implant.[2,16] Immunosterilization suppresses reproductive activity, but also reduces heifer performance unless implanted with an estrogenic or androgenic implant.[1,2,12,31] The only long-acting progestin available for the commercial use of suppressing estrus and ovulation is the feed additive melengestrol acetate (**MGA**). Daily feeding of MGA is convenient for feedlot heifers, but impractical for grazing heifers because MGA must be consumed daily. Injection of a commercially unavailable depot-formulated MGA prevented pregnancy in grazing heifers, but weight gain was not increased.[15,19]

Norgestomet (**NOR**), another progestin, was previously available commercially in the form of a 6 mg NOR (240 μg NOR/d) implant for short-term ovulation and estrus suppression and as an estrus synchronization tool.[14,25,33] A commercially unavailable 48 mg NOR (320 μg NOR/d) implant prevented pregnancy for up to 154 d in 91% of grazing heifers.[18] However, recurrent estrus in 35% of the heifers may have prevented a further potential increase in performance. We hypothesized that an implant containing > 48 mg NOR would completely inhibit reproductive activity. The objective of this study was to assess the efficacy of long-acting, erodible implants containing 100 or 150 mg NOR over a grazing period of 240 d on performance and pregnancy inhibition in grazing postpubertal beef heifers.

Materials and Methods

Animal handling procedures were approved by the University of Arkansas Institutional Animal Care and Use Committee (protocol #13037) and followed guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching.[13] The study was conducted at the University of Arkansas Stocker Cattle Receiving and Backgrounding Unit (Savoy, AR).

Animal Processing and Study Inclusion

Crossbred beef heifers ($n = 278$) arrived at least 10 d before treatment administration to become acclimated to the study site. At arrival, initial body weight (BW) used for allocation and treatment assignment was obtained. Cattle in ill health were excluded from study consideration. Ears were palpated and any existing growth promoting implants were located and excised. Heifers were identified with duplicate ear tags that did not disclose experimental treatments, administered bacterial and viral vaccinations[a,b,c] and dewormed.[d] Pregnancy status and reproductive tract scores (**RTS**; 1 = immature, 5 = corpus luteum present[3]) were assigned via transrectal palpation and ultrasonography[e] by a single trained professional. Heifers diagnosed as pregnant or categorized as having an infantile tract (RTS = 1) or prepubertal (RTS = 2 or 3) were excluded from study consideration. Animals identified as having follicular cysts received a 100 μg injection of GnRH.[f] After the exclusion of unacceptable cattle, 240 healthy, nonpregnant heifers (initial BW = 763 ± 7.5 lb [346 ± 3.40 kg]) were enrolled in the study.

Study Design, Animal Management, and Data Collection

Heifers were stratified by BW and assigned to 80 blocks (3 heifers/block). Blocks were allocated randomly to 1 of 5 mixed fescue-bermudagrass pastures (48 heifers/pasture; 24.7 to 46.2 acres [10.0 to 18.7-ha] pastures). Animals were assigned randomly within block to receive 1 of 3 commercially unavailable implants containing 0 (**control**), 100, or 150 mg NOR (randomized complete block design). Control implants contained 93% lactose: 7% (w/w) erodible material (4 pellets/implant dose), whereas 100 and 150 mg NOR implants contained 82% NOR (11β-methyl-17α-acetoxy-19-norprogesterone): 18% (w/w) erodible material (4 or 6 pellets/implant dose; 100 or 150 mg NOR, respectively). The 100 and 150 mg NOR dosages were formulated to deliver 417 and 625 μg NOR/d, respectively, for 240 d. Delivery rates were greater than the conventional 6 mg (240 μg NOR/d) implant used for short-term ovulation suppression in estrus synchronization and those used for long-term pregnancy prevention (240 to 320 μg NOR/d[18]). Implants were administered using product-specific devices for each implant (d 0). Implants were placed subcutaneously in the middle one-third of the back of 1 ear per each animal and at least 1 inch (2.5 cm) from ear tags. Clean and dry ears were implanted without cleaning. Ears that were wet or contaminated with manure and/or mud were scrubbed with a brush soaked in a chlorhexidine solution[g] before implanting using a "scrape, brush, and disinfect" technique on the ear. Stylets of implant devices were disinfected with chlorhexidine[g] after treating each animal. Following implant administration, implant sites were lightly palpated to confirm administration was successful; however, no attempt was made to close the implant injection site. On d 50 and 100, implant sites were assessed by personnel blinded to treatments. Physical evaluation of the implant site was prohibited to avoid dispersion of the implant and an abnormal release profile. Documentation included whether an implant was detected (no = 0 or yes = 1) and whether reactions were observed at the implant site (no reaction, fluid present, or abscessed). No attempt was made to quantify partial or missing implants.

Cattle grazed mixed fescue-bermudagrass pastures with ad libitum access to a mineral-vitamin mix (18% Ca, 3% P, 1% Mg, 0.10% K, 1,000 mg Cu/kg, 26 mg Se/kg, 3,750 mg Zn/kg, 661,000 IU Vitamin A/kg, 44,000 IU Vitamin D/kg, and 220 IU Vitamin E/kg).[h] No growth promoters or feed additives were fed during the study. Water was available ad libitum. Heifers were placed with fertile bulls from d 7 to 200 (≥ 1 bull/25 heifers). Bull breeding soundness evaluations[11] were conducted on d 0, 50, 100, and 150. In addition to pretreatment BW, heifers were weighed on d 50, 100, 150, 200, and 240. Pregnancy was diagnosed (0 = nonpregnant or 1 = pregnant) by transrectal ultrasonography on d 50, 100, 150, 200, and 240 by personnel proficient in corpus luteum and fetal measurements. Presence of a viable embryo (heartbeat) and the estimated duration of the potential pregnancy as being ≥ 35 d were criteria used to classify heifers as pregnant. Animals diagnosed pregnant were removed from the study at pregnancy diagnosis.

Animals were observed daily for adverse reactions or health abnormalities and to ensure adequate pasture, mineral-vitamin mix, and water availability. Observations were documented by personnel blinded to treatments. Adverse events were defined as any unfavorable or unintended observations in any animal, and all such events were recorded regardless of whether or not they were considered related to experimental treatments. Therapeutic treatments were documented from the time that experimental treatments were administered through study completion. One heifer (100 mg NOR) died on d 131. Histopathological examination[i] confirmed necrotic mastitis as the cause of death. Data from the heifer were retained in all statistical analyses.

Statistical Analyses

Performance data were analyzed using the MIXED procedure of SAS[j] by means of a compound symmetry covariance structure. Denominator degrees of freedom were estimated using the Kenward-Rogers option. Adherence of data to the assumptions of the statistical test was established. Weight data were analyzed as repeated measures. Fixed (main) effects included in the model were treatment and day, as well as the 2-way interaction, whereas block was included as a random effect and heifer as the experimental unit. Day was included as a repeated effect. Average daily gain data were analyzed as a randomized design. Treatment was the fixed effect, whereas block was included as a random effect and heifer as the experimental unit in the model. Heifer pregnancy and implant site observation data were analyzed using the GLIMMIX procedure of SAS. Binary data were tested using a binomial distribution, cumulative logit link function, variance components covariance structure, and block as a random effect. In addition, the effect of treatment on heifer pregnancy was evaluated by survival analysis using the log-rank method of the LIFETEST procedure of SAS. Phi correlation coefficients (φ) for relationship between heifer implant site observation and pregnancy data due to treatment were determined using the FREQ procedure of SAS. Orthogonal contrasts were used to assess the effects of control vs NOR (100 or 150 mg NOR) and dose efficacy (100 vs 150 mg NOR). Statistical significance was declared at $P \leq 0.10$.

Results and Discussion

Growth Performance

Heifers that received 100 or 150 mg NOR gained weight at a faster rate ($P < 0.05$) compared to control heifers (1.04 or 1.06 vs 0.84 lb [0.47 or 0.48 vs 0.38 kg]/d, respectively; Table 1). These gains corresponded to a 24 or 26% (100 or 150 mg NOR, respectively) increase in ADG when compared to control heifers. The response in ADG due to NOR implants was not dose dependent, as the rate of gain did not differ

Table 1. Effect of Norgestomet (**NOR**) implant dose on performance in grazing postpubertal beef heifers.

	NOR, mg				Contrast*	
Item	**0**	**100**	**150**	**SEM**	**1**	**2**
Heifers	80	80	80			
Initial BW, lb	766.8	762.4	761.7	7.1	0.59	0.95
Final BW,† lb	964.7	1015.2	1017.2	18.1	0.14	0.99
ADG,‡ lb/d	0.84	1.04	1.06	0.04	<0.05	0.44

* 1: control (0 mg NOR) vs NOR (100 or 150 mg NOR); 2: dose efficacy (100 vs 150 mg NOR).
† Final BW for nonpregnant heifers remaining on study (*n* = 6, 75, or 74; 0, 100, or 150 mg NOR, respectively).
‡ Mean ADG from d 0 to 240 calculated for nonpregnant heifers remaining on study (*n* = 6, 75, or 74; 0, 100, or 150 mg NOR, respectively).

(P = 0.44) between heifers receiving 100 or 150 mg NOR. Final BW did not differ (P = 0.14) between treatments. Increases in heifer performance similar to those described here have been reported elsewhere. Geary et al[18] reported grazing heifers receiving 36 or 48 mg NOR for 74 d gained weight at a faster rate than heifers treated with 0 mg NOR. Similarly, Hill et al[20] reported heifers receiving an implant containing 50 mg NOR for 122 d had greater BW gains than heifers with placebo implants. Previous studies have demonstrated that treatment with the conventional 6 mg NOR implant in the absence of a functional corpus luteum maintained persistent dominant ovarian follicles[5,29,32] and increased circulating 17β-estradiol concentrations.[5,17,23] Therefore, increased ADG during NOR treatment is likely due to suppressing ovulation while maintaining sufficient endogenous estradiol production from persistent dominant ovarian follicles to elicit growth.

Reproductive Activity

Implants did not eliminate pregnancy at any NOR dosage (Table 2). Heifer pregnancy rates were 90.0 (90% CI = [82.9, 94.4]), 8.9 (90% CI = [4.8, 15.8]), and 12.5% (90% CI = [7.5, 20.0]) when administered 0, 100, or 150 mg NOR, respectively. Heifers that received 100 or 150 mg NOR experienced lower pregnancy rates (P < 0.0001) and longer pregnancy inhibition (P < 0.0001; Figure 1) than control heifers. By d 150, 88.8% (71/80) of control heifers were pregnant, and 90.0% (72/80) were pregnant by d 200. Conversely, 100 or 150 mg NOR prevented pregnancy in at least 92.5% (3/79 or 6/80; 100 or 150 mg NOR, respectively) of heifers for 200 d. Pregnancy rates of NOR treated heifers were not dose dependent, as the pregnancy rates did not differ (P = 0.46) between heifers receiving 100 or 150 mg NOR. When comparing the pregnancy rates for each treatment group from study d 150 to d 240, the pregnancy rates did not differ (P = 0.67) for heifers receiving 0 mg NOR during that time; however, pregnancy rates tended to increase (P < 0.10) for heifers receiving 100 mg and 150 mg NOR from d 150 to 240 indicating a tendency for a decreasing level of pregnancy inhibition toward the end of the study period.

The short-term use of the conventional 6 mg NOR implant has been reported to suppress ovulation[10,29] and prevent normal luteal development.[8,20] Moreover, NOR treatment may decrease fertility by decreasing oocyte viability with the prolonged development of persistent dominant ovarian follicles[5,26,28] and alter the uterine endometrium to prohibit embryonic development.[6,27] Accordingly, the effect of NOR treatment in reducing pregnancy rates may be attributed to the cumulative effects of suppressed ovulation, abnormal luteal development, decreased oocyte fertility, and/or altered uterine environment.

Pregnancy inhibition similar to the present study has been described previously. Geary et al[18] reported the pregnancy rates of heifers exposed to bulls for 75 d after implantation were 96, 29, 6, and 4% for heifers receiving 0, 24, 36, and 48 mg NOR, respectively. Moreover, in a second experiment, the pregnancy rates of heifers exposed to bulls for 80 d beginning 75 d after implantation were 86, 36, 19, and 9% for heifers receiving 0, 24, 36, and 48 mg NOR, respectively. The calculated NOR delivery rates of the implants evaluated in Geary et al[18] were 160, 240, and 320 µg NOR/d for implants containing 24, 36, and 48 mg NOR, respectively.

The calculated NOR delivery rates of the implants used in the present study were 417 and 625 µg/d for implants containing 100 and 150 mg NOR, respectively. Accordingly, total pregnancy inhibition was expected among all heifers receiving 150 mg NOR implants. The efficacy of NOR implants in suppressing ovulation and estrus has been shown to vary with the stage of estrous cycle when implanted. Yavas et al[35] reported that a 24 mg NOR (160 µg NOR/d) implant was more effective in suppressing ovulation and estrus for 63 d when implanted on d 7 of the estrous cycle rather than later in the cycle. Similarly, results from Brink and Kiracofe[7] suggest that NOR suppresses ovulation better if administered early in the estrous cycle. In their study, higher conception rates (62.5 vs 46.0%) were reported in cows bred after receiving the conventional 6 mg NOR implant earlier (≤ d 11) in the estrous cycle than in cows that received the treatment later (> d 11) in the cycle. In the present study, heifers were treated without regard to estrous cycle stage. Accordingly, greater pregnancy

Table 2. Effect of Norgestomet (**NOR**) implant dose on pregnancy cumulative percent distribution in grazing postpubertal beef heifers.

Interval, d	NOR, mg			SEM	Contrast*	
	0	100	150		1	2
	----------------------- % (90% CI) ----------------------					
0 to 50†	33.8 (27.0, 41.3)	0.0	5.0 (2.6, 9.5)	2.12	1.00	1.00
51 to 100	81.3 (72.9, 87.5)	2.5 (0.8, 7.8)	6.3 (3.0, 12.6)	2.96	<0.0001	0.27
101 to 150	88.8 (81.4, 93.4)	2.5 (0.8, 7.9)	6.3 (3.0, 12.6)	2.69	<0.0001	0.27
151 to 200	90.0 (82.9, 94.4)	3.8 (1.5, 9.5)	7.5 (3.9, 14.1)	2.83	<0.0001	0.33
201 to 240	90.0 (82.9, 94.4)	8.9 (4.8, 15.8)	12.5 (7.5, 20.0)	3.44	<0.0001	0.46

*1: control (0 mg NOR) vs NOR (100 or 150 mg NOR); 2: dose efficacy (100 vs 150 mg NOR).
† Heifers confirmed nonpregnant d 0 by transrectal ultrasonography (Aloka 500V, 5.0-MHz linear transducer).

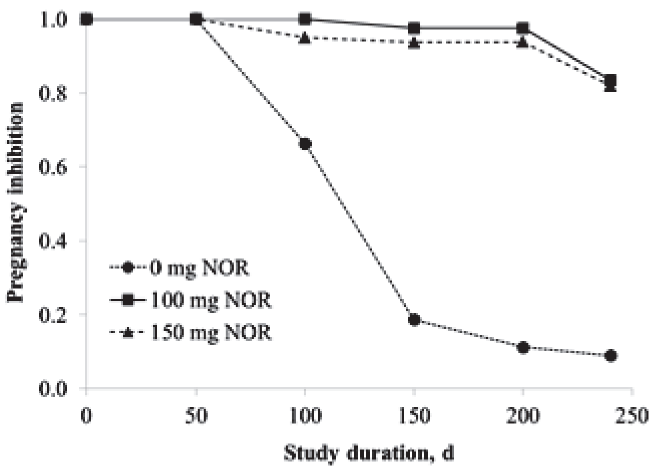

Figure 1. Estimated effect of Norgestomet (NOR) implant dose on pregnancy inhibition in grazing postpubertal beef heifers after exposure to fertile bulls from d 7 to 200. Heifers receiving 100 or 150 mg NOR implants experienced longer pregnancy inhibition ($P < 0.0001$) than control (0 mg NOR) heifers. Heifers receiving 100 or 150 mg NOR implants experienced comparable ($P = 0.97$) pregnancy inhibition.

inhibition may have been observed in the NOR treated heifers if all heifers were implanted early in the estrous cycle.

Implant Site Observations

No evidence of abscesses, fluid around the implant site, or swelling was observed throughout the study. Implants were visible in all heifers on d 0 regardless of treatment. On d 50, implants were observed in 5.0 (90% CI = [1.3, 12.7]), 71.3 (90% CI = [50.3, 73.3]), and 83.8% (90% CI = [72.3, 90.5]) of heifers administered 0, 100, or 150 mg NOR, respectively (Table 3). Visible implants were dose dependent. Implants were located in a greater ($P < 0.0001$) number of heifers receiving 100 or 150 mg NOR than control heifers, and the number of visible implants in heifers implanted with 150 mg NOR was greater ($P < 0.05$) than heifers that received 100 mg NOR. Visible implants did not differ ($P \geq 0.77$) across treatments by d 100; however, the number of visible implants was numerically greater in heifers that received 100 or 150 mg NOR than control heifers. No correlation ($P \geq 0.17$) was found between the incidence of visible implants at d 100 and pregnancy rates at d 240 for heifers implanted with 100 or 150 mg NOR (φ = -0.07 or -0.16, respectively). Therefore, the 100 and 150 mg NOR implants seemingly provided the stable release of NOR throughout the study while the erodible material slowly degraded.

Conclusions

The objective of this study was to assess the efficacy of long-acting, erodible implants containing 100 or 150 mg NOR over a 240 d grazing period on performance and pregnancy inhibition in grazing postpubertal beef heifers. Norgestomet implants did not eliminate pregnancy at any dosage. However, 100 and 150 mg NOR implants inhibited pregnancy in 92.5% of grazing postpubertal heifers for at least 200-d and produced a ≥ 24% increase in ADG. These results suggest 100 and 150 mg NOR implants were effective in decreasing unintended pregnancy in grazing heifers while avoiding pregnancy-induced reductions in performance. However, to prevent pregnancy in all implanted heifers, a higher dosage of NOR may be required and the estrous cycle stage when the implant is administered may warrant consideration.

Endnotes

[a] CattleMaster 4 + VL5, Zoetis, Parsippany, NJ
[b] Pinkeye Shield XT4, Elanco Animal Health, Greenfield, IN
[c] UltraChoice 8, Zoetis, Parsippany, NJ
[d] Dectomax, Zoetis, Parsippany, NJ
[e] Aloka 500V, 5.0-MHz linear transducer, Corometrics Medical Systems, Wallingford, CT
[f] Factrel, gonadorelin hydrochloride, Zoetis, Parsippany, NJ
[g] Nolvasan, Zoetis, Parsippany, NJ
[h] Vigortone 3V6 Beef Minerals, Vigortone Ag Products, Brookville, OH
[i] University of Arkansas Veterinary Diagnostic Laboratory, Fayetteville, AR
[j] SAS Inst., Inc., Cary, NC

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Table 3. Effect of Norgestomet (**NOR**) implant dose on the percentage of grazing postpubertal beef heifers with visible implants.

	NOR, mg				Contrast*	
Day†	**0**	**100**	**150**	**SEM**	**1**	**2**
	--------------------------- % (90% CI) ---------------------------					
50	5.0 (1.3, 12.7)	71.3 (50.3, 73.3)	83.8 (72.3, 90.5)	5.14	<0.0001	<0.05
100	0.0	23.8 (15.7, 32.2)	28.8 (17.5, 34.5)	3.39	1.00	0.77

*1: control (0 mg NOR) vs NOR (100 or 150 mg NOR); 2: dose efficacy (100 vs 150 mg NOR).
† Implants visible in all heifers on d 0.

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References

1. Adams TE, Adams BM. Reproductive function and feedlot performance of beef heifers actively immunized against GnRh. *J Anim Sci* 1990;68:2793-2802. doi:10.2527/1990.6892793x.
2. Adams TE, Dunbar JR, Berry SL, Garrett WN, Famula TR, Lee YB. Feedlot performance of beef heifers implanted with Synovex-H: Effect of melengestrol acetate, ovariectomy or active immunization against GnRH. *J Anim Sci* 1990;68:3079-3085. doi:10.2527/1990.68103079x.
3. Anderson KJ, LeFever DG, Brinks JS, Odde KG. The use of reproductive tract scoring in beef heifers. *Agri-Practice* 1991;12:19-26.
4. Bennett BW, Clayton RP, Cravens RL, Lloyd WR. Slaughter weight loss attributable to pregnancy in feedlot heifers. *Mod Vet Pract* 1984;65:677-679.
5. Borchert KM, Farin CE, Washburn SP. Effect of estrus synchronization with norgestomet on the integrity of oocytes from persistent follicles in beef cattle. *J Anim Sci* 1999;77:2742-2748. doi:10.2527/1999.77102742x.
6. Breuel KF, Lewis PE, Schrick FN, Lishman AW, Inskeep EK, Butcher RL. Factors affecting fertility in the postpartum cow: Role of the oocyte and follicle in conception rate. *Biol Reprod* 1993;48:655-661. doi:10.1095/biolreprod48.3.655.
7. Brink JT, Kiracofe GH. Effect of estrous cycle stage at Syncro-Mate B treatment on conception and time to estrus in cattle. *Theriogenology* 1988;29:513-518. doi:10.1016/0093-691x(88)90253-1.
8. Burns PD, Spitzer JC, Bridges Jr. WC, Henricks DM, Plyler BB. Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone release and development and function of corpora lutea in suckled beef cows. *J Anim Sci* 1993;71:983-988. doi:10.2527/1993.714983x.
9. Busby D, Loy D, Rouse G. Effect of MGA on performance, sexual behavior, carcass quality and tenderness in mixed-sex pens of cattle. *2001 Beef Research Report* A. S. Leaflet R1743. Iowa State University, Ames. 2001.
10. Cavalieri J, Kinder JE, Fitzpatrick LA. Duration of ovulation suppression with subcutaneous silicone implants containing norgestomet in *Bos indicus* heifers and cows. *Anim Reprod Sci* 1998;51:15-22. doi:10.1016/s0378-4320(98)00058-x.
11. Chenoweth PJ, Spitzer JC, Hopkins FM. A new bull breeding soundness evaluation form, in *Proceedings*. Ann Mtng Soc for Theriogenology, San Antonio, TX, 1992;63-71.
12. Cook RB, Popp JD, McAllister TA, Kastelic JP, Harland R. Effects of immunization against GnRH, melengestrol acetate, and a trenbolone acetate/estradiol implant on growth and carcass characteristics of beef heifers. *Theriogenology* 2001;55:973-981. doi:10.1016/s0093-691x(01)00458-7.
13. FASS. Guide for the care and use of agricultural animals in agricultural research and teaching. Consortium for developing a guide for the care and use of agricultural research and teaching. Association Headquarters, Champaign, IL. 2010.
14. Favero RJ, Faulkner DB, Kesler DJ. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J Anim Sci* 1993;71:2594-2600. doi:10.2527/1993.71102594x.
15. Floyd JG, Ott RS, Weigel RM, Zinn GM, Hixon JE. Inhibition of pregnancy in heifers, using a repositol formulation of melengestrol acetate. *Am J Vet Res* 1989;50:1493-1495.
16. Garber MJ, Roeder RA, Combs JJ, Eldridge L, Miller JC, Hinman DD, Ney JJ. Efficacy of vaginal spaying and anabolic implants on growth and carcass characteristics in beef heifers. *J Anim Sci* 1990;68:1469-1475. doi:10.2527/1990.6851469x.
17. Garcia-Winder M, Lewis PE, Townsend EC, Inskeep EK. Effects of norgestomet on follicular development in postpartum beef cows. *J Anim Sci* 1987;64:1099-1109. doi:10.2527/jas1987.6441099x.
18. Geary TW, Reeves JJ, Schafer DW, Evans RR, Randel RD, Rutter LM, Sasser RG, Guardia R, Alexander B, Holcombe D, Hanks DR, Faulkner DB. Norgestomet implants prevent pregnancy in beef heifers on pasture. *J Anim Sci* 1997;75:3089-3093. doi:10.2527/1997.75123089x.
19. Hill GM, Richardson KL, Utley PR. Feedlot performance and pregnancy inhibition of heifers treated with depot-formulated melengestrol acetate. *J Anim Sci* 1988;66:2435-2442. doi:10.2527/jas1988.66102435x.
20. Hill GM, Lucas DM, Richardson KL, Baker JF, Kiser TE. Ovarian luteal activity and reproductive performance of heifers with norgestomet prototype implants. *Theriogenology* 1992;37:619-629. doi:10.1016/0093-691x(92)90142-e.
21. Horton GMJ, Manns JG, Nicholson HH, Harrop GA. Behavioral activity, serum progesterone and feedlot performance of heifers fed melengestrol acetate and monensin. *Can J Anim Sci* 1981;61:695-702. doi:10.4141/cjas81-084.
22. Jim GK, Ribble CS, Guichon PT, Thorlakson BE. The relative economics of feeding open, aborted, and pregnant feedlot heifers. *Can Vet J* 1991;32:613-617.
23. Kojima N, Stumpf TT, Cupp AS, Werth LA, Roberson MS, Wolfe MW, Kittok RJ, Kinder JE. Exogenous progesterone and progestins as used in estrous synchrony regimens do not mimic the corpus luteum in regulation of luteinizing hormone and 17β-estradiol in circulation of cows. *Biol Reprod* 1992;47:1009-1017. doi:10.1095/biolreprod47.6.1009.
24. Kreikemeier KK, Unruh JA. Carcass traits and the occurrence of dark cutters in pregnant and nonpregnant feedlot heifers. *J Anim Sci* 1993;71:1699-1703. doi:10.2527/1993.7171699x.
25. Machado R, Kesler DJ. Efficacy of norethindrone acetate and norgestomet implants in suppressing estrus in female beef cattle. *Drug Dev Ind Pharm* 1996;22:1211-1216. doi:10.3109/03639049609063239.
26. Mihm M, Curran N, Hyttel P, Knight PG, Boland MP, Roche JF. Effect of dominant follicle persistence on follicular fluid oestradiol and inhibin and on oocyte maturation in heifers. *J Reprod Fertil* 1999;116:293-304. doi:10.1530/jrf.0.1160293.
27. Moffatt RJ, Zollers WG Jr, Welshons WV, Kieborz KR, Garverick HA, Smith MF. Basis of norgestomet action as a progestogen in cattle. *Domest Anim Endocrin* 1993;10:21-30. doi:10.1016/0739-7240(93)90005-v.
28. Revah I, Butler WR. Prolonged dominance of follicles and reduced viability of bovine oocytes. *J Reprod Fertil* 1996;106:39-47. doi:10.1530/jrf.0.1060039.
29. Savio JD, Thatcher WW, Badinga L, de la Sota RL, Wolfenson D. Regulation of dominant follicle turnover during the oestrous cycle in cows. *J Reprod Fertil* 1993;97:197-203. doi:10.1530/jrf.0.0970197.
30. Sides GE, Vasconcelos JT, Borg RC, Turgeon OA, Koers WC, Davis MS, Vander Pol K, Weigel DJ, Tucker CM. A comparison of melengestrol acetate fed at two dose levels to feedlot heifers. *Prof Anim Sci* 2009;25:731-736. doi:10.15232/S1080-7446(15)30782-8.
31. Stevens JD, Sosa JM, deAvila DM, Oatley JM, Bertrand KP, Gaskins CT, Reeves JJ. Luteinizing hormone-releasing hormone fusion protein vaccines block estrous cycle activity in beef heifers. *J Anim Sci* 2005;83:152-159. doi:10.2527/2005.831152x.
32. Taylor C, Rajamahendran R, Walton JS. Ovarian follicular dynamics and plasma luteinizing hormone concentrations in norgestomet-treated heifers. *Anim Reprod Sci* 1993;32:173-184. doi:10.1016/0378-4320(93)90089-A.
33. Thompson KE, Stevenson JS, Lamb GC, Grieger DM, Löest CA. Follicular, hormonal, and pregnancy responses of early postpartum suckled beef cows to GnRH, norgestomet, and prostaglandin $F_{2\alpha}$. *J Anim Sci* 1999;77:1823-1832. doi:10.2527/1999.7771823x.
34. Walker CE, Birkelo CP, Stanton TL, Flack DE, Bennett BW, Cravens RL. Pregnancy effects on feed intake, gain and feed efficiency of finishing heifers. *Agri-Pract* 1988;9:13-15.
35. Yavas Y, de Avila DM, Reeves JJ. Effectiveness of norgestomet implants in suppressing ovulation and estrus in heifers varies with stage of estrous cycle when implanted. *Can J Anim Sci* 2000;80:729-732. doi:10.4141/A99-111.