RELATIONSHIP BETWEEN FEED EFFICIENCY AND REPRODUCTIVE MEASUREMENTS IN BEEF CATTLE

by

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Abstract

It is important for animals to be feed efficient and reproductively sound to optimize profits for cow- calf producers. The objective of this study was to determine the relationship between feed efficiency and reproductive performance. Feed efficiency measures included residual feed intake (RFI), feed to gain ratio (F:G) and daily dry matter intake (DMI). Reproductive measurements were pregnancy rate, first service conception rate, pregnancy type (AI, natural. open), calving percentage, calving day (CD) and age at first calving. Two data sets which included 136 crossbred Angus females sired by bulls with high or low RFI estimated breeding values (EBV) with multiple parity information and 56 purebred Hereford heifers with their first parity calving information were analyzed. Initially, the crossbred Angus females were analyzed based on their phenotypic RFI values. There was no difference in pregnancy rate between the feed efficiency measures. Second parity pregnant females had lower (F:G) with first service conception (P=0.053), and pregnancy types (P=0.014) than the open (less efficient) females. In parity 5, phenotypically efficient RFI Angus females were pregnant to first service conception versus inefficient RFI Angus females (P=0.052) and those with lower DMI were diagnosed pregnant (P=0.0002). When evaluated as a repeated trait, RFI was not a significant indicator of CD (P=0.514). Crossbred Angus females were analyzed based on their sire's RFI EBV and grouped accordingly into high (inefficient) or low (efficient) RFI sires. Females sired by high or low RFI (EBV) bulls showed no difference for the reproductive traits, except for a tendency for inefficient sired heifers to have a lower calving percentage in parity 2 (P=0.048). When CD was analyzed as a repeated measure, no difference between sire groups was found (efficient CD of 35.64 d, inefficient CD of 34.23, p = 0.789). In the Hereford heifers, RFI was not an indicator of CD (P = 0.774). There was also no difference in RFI between pregnant and open Hereford females with pregnant females having an LSMean of 0.11 kg/d and the open females having an LSMean of 0.14 kg/d (P = 0.860). Further research needs to be done to confirm any relationships between feed efficiency and reproduction.

Keywords: Feed Efficiency, Reproduction, Residual Feed Intake

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Chapter 1 - Literature Review

Introduction

Today's beef cattle industry is constantly impacted by the price of feed. Selecting animals that are more feed efficient can save producers money in the cattle industry. Several traits estimate feed efficiency and are moderately heritable as a measure of feed efficiency. Residual feed intake (RFI) has become a highly discussed topic during the last 10 years, although it has been around for much longer. RFI was defined by Koch et al. (1963). Other measures of feed efficiency include feed to gain ratio (F:G) and daily dry matter intake (DMI).

Residual feed intake can be calculated by measuring an animal's actual feed intake and estimating what the animal should be eating based on gain and production. Estimated feed intake is then subtracted from actual feed intake. An efficient RFI animal will eat less than what is estimated for them, resulting in a negative number. An inefficient RFI animal's calculation will be high because the animal consumes more than what is expected. Selection for DMI amount doesn't necessarily identify an efficient animal because it does not account for the output of the animal. When selecting for F:G, it is impossible to know if intake is decreasing or if gain is increasing.

Reproduction is economically important in the cow-calf industry. Profit for a producer often comes from the calves sold. Important reproductive traits to measure are pregnancy percentage, first service conception, pregnancy type, calving percentage, calving day, and age at first calving. Pregnancy percentage is important because a female needs to be able to become bred to retain in most herds. When the dam is being bred at an earlier date and the calf is sired by a genetically better sire, both have positive economical impacts on profit and therefore first service conception should be measured. Pregnancy type is important again to determine if the calf is being sired by the more valuable sire versus the natural service option or the females remaining open or not pregnant. Not all animals that are diagnosed pregnant will successfully produce a calf, and so calving rate is an important measurement. Calving days and age at first calving is important because females that produce calves earlier in their life and earlier in the calving season are more beneficial to the herd, and will produce more calves throughout their years versus the females that continuingly calve later in the season each year.

What is Feed Efficiency and Why Measure It?

A feed efficient animal is one that uses feed to gain pounds at a more efficient rate. A feed efficient animal is not one that eats a lot but gains little. It is also not an animal that its very little but also gains very little in a slow manner. Measuring for feed efficiency can be costly but profitable. Archer and Barwick (1999) in Australia found that measuring for RFI at costs of $450 can still be profitable when selling to the Japanese market. They found it less profitable to the domestic grass-fed industry at this testing cost, but when testing costs were lowered to $150, it was still profitable. The Japanese market pays much higher premium for beef which is of higher quality than local supermarket beef. The selected animals can have an increase in efficiency between 3% and 42%. The increase in genetic merit can justify the cost of testing.

Residual Feed Intake

Residual feed intake can be calculated by measuring an animal's actual feed intake and estimating what the animal should be eating based on gain and production as described by Koch et al. (1963). RFI is a desirable method of determining feed efficiency because it takes into the account the weight and growth of the animals when determining the estimate of what an animal should eat. Other feed efficiency measurements are naive in accounting for these factors that affect the gain of an animal. To determine RFI values, subtract the predicted feed intake from the actual feed intake. An efficient RFI animal will eat less than what is predicted for them. This would result in a negative number. An inefficient RFI animal's calculation will be positive because the animal consumes more than what is expected. By selecting for animal that has a negative RFI value or is efficient, then you are selecting for animals that eat less but gain the same. This would save a producer money by having to buy less feed, or putting less input into the animal while still receiving the same output. RFI is has been estimated to be moderately heritable. Archer et al. (1998) at the NSW Agricultural Research Centre in Trangie, Australia with 1166 of British-descent beef cattle estimated it to be 0.46 ± 0.07, in the United States Koch et al. (1963) estimated it to be 0.28 ± 0.11 with 1324 calves consisting of Hereford, Angus, and Shorthorn and Arthur et al. (2001) also in Australia estimated it at 0.39 ± 0.03 with 1,180 British descent animals. Archer et al. (1994) found RFI to have higher repeatability than gross efficiency and therefore is a more useful measurement of efficiency. Gross efficiency was defined by Archer et al. (1994) as being ratio between feed inputs and production output, which is the same concept as the feed to gain ratio.

RFI Values in Grazing versus Feedlot Diets

Starting in 2002, the Animal Genetics and Breeding Unit (AGBU) measured net feed intake on Angus and Hereford cattle. The cattle were measured for feed intake at different test stations. Since the animals were fed at different test stations, they were also fed different diets. These animals were divided into two different groups based upon their diets, NFI-P and NFI-F. NFI-P, was based on the animals that were fed more of a post-weaning grazing diet. The NFI-F group was fed more of finishing diet, similar to what cattle would be feed in a feedlot setting. Heritability of the NFI-P diet was estimated to be 0.42 ± 0.05 and the heritability of NFI-F to be 0.39 ± 0.09. The genetic correlation between NFI-I and NFI-P was 0.59 ±0.17 (Animal Genetics and Breeding Unit, 2007). From this they concluded that there was a difference in the way the genes interacted in the grazing versus the finishing diets. As a result, animals that are fed a different diet not only gain differently but their residual feed intake values or net feed intake values are not the same but could be similar in meaning.

Feed to Gain Ratio

Feed to gain ratio is a common measure of feed efficiency. In a feed to gain ratio the feed intake (input) of the animal and the pounds of gain (output) are measured. However, selecting on a ratio can cause issues. An animal with low intake or high gain can produce similar feed to gain ratio results. Therefore could be selecting for animals that eat very little and gain very little and are slow to grow or they eat a lot more than what they should and could be gaining a lot of fat instead of muscle which is less desirable. Arthur et al. (2001) estimated the heritability of feed to gain ratio to be 0.66 ± 0.05.

Daily Dry Matter Intake

Daily dry matter intake (DMI) is how much the animal consumes minus the moisture content of the feed. Dry matter is based on a percentage of the total kilograms that the animal eats. The percentage that is used to figure DMI is dependent on the type and quality of the feed that is being feed. The percentage represents the amount of dry matter found in the feed. A high moisture food has a lower percentage ofDMI. Dry matter intake is figured by the average amount of dry matter consumed of a specified period of time. By selecting solely on DMI, you are only accounting for the animal inputs and not measuring the animal's output or weight gain which is crucial when correctly figuring feed efficiency.

Measures of Reproduction and the Importance

Profit within a cow-calf operation is largely based on the calf crop percentage. Without a calf to sell, the producer will lose money. While a 100% calf crop is optimal and may maximize profit, it is rarely achieved. Calf loss can occur due to several reasons including; nutrition, health, management, physiological factors, and infertility. Infertility among cow-calf producers causes an annual loss of $1.06 billion and affects 42.5 million cows (Lamb, 2008). Infertility can be reduced by selecting for improved reproductive traits. Reproductive traits that may have an economic impact on the calf crop are normally estimated to be lowly heritable (Cammack et al.,

2008) and so have traditionally improved by management rather than selection. However, the economic importance of fertility has increased interest in incorporating reproductive traits into breeding objectives.

Calving date (CD), pregnancy rate (PREG), and first service conception rate (FSC), are among several reproductive traits that can have an economic impact on the percent of calf crop. Ritchie (1995) observed that approximately 50% of the relative economic values of beef industry traits are related to reproduction. Heifers that fail to achieve pregnancy after exposure to a bull can be culled with a net loss of $86 (Lamb, 1999). If a producer waits until after the winter months to diagnose a heifer as non-pregnant, subsequent culling may lead to a net loss of $133 (Lamb, 1999). Increase in genetic potential for reproductive traits and a longer growing season for the calf are both beneficial aspects of heifers pregnant to first service artificial insemination and which can cause an average profit of $163 versus a heifer mated via natural service, which average profit was $83 (Lamb, 1999). Heifers or cows bred at first service allow for a greater growing opportunity, when an operation has a fixed weaning date. This increase in growing time leads to more pounds. Heavier calves may then return producer a greater profit for the producer. Calving earlier allows the heifer or cow sufficient amount of time to return to proper cycling. Failure of 15 to 20% of the nation's cow herd to wean a calf annually is due to cows that fail to rebreed within 85 days after calving (Williams, 1990). Lack of recording data on these traits has also caused selection to be slowed because not much data has been turned in to associations for these traits.

In order prevent bias in CD data that contains dams that do not calve, a penalty value is given to the dam that don't calve. By adding a penalty value to the calving records for the dams that did not calve, they are able to be included in the analysis of age at first calving (AFC) and CD. By simply leaving those animals out of the analysis would create biased results. The question is what penalty value is sufficient to penalize the dams that did not calve but not to over exaggerate and affect the data results. Donoghue et al. (2004), showed that a penalty value of 21 days is sufficient. Twenty-one days is the length of the estrous cycle in beef cattle which assumes that the females could have potentially been bred in the following heat cycle (Donoghue et al., 2004).

Relationship between Feed Efficiency and Reproduction

Profitability in a herd is determined by the relationship of inputs and outputs. An animal not only needs to consume less, but also needs to output well in gain and reproduction. In order for a cow-calf producer to be profitable they should achieve excellent feed efficiency and reproduction without compromising the other. An animal with favorable feed efficiency is of no importance if she cannot produce a calf. In contrast, a producer does not want animals that reproduce every year but consume a lot of feed and produce little liveweight gain as the income for a cow-calf producer comes from selling the calves on a weight basis.

Relationship between RFI and Reproduction

Only a few research studies to date have measured the reproductive performance of dams and heifers when compared to residual feed intake. One of the first studies to analysis the topic was from Arthur et al. (2005) which involved a high and low selection line. Arthur et al. (2005) collected data on 185 Angus cattle through 3 mating seasons. Traits that were considered were

PREG, calving rate, CD, calf birth weight, FSC, and birth weight. Heifers were identified as either high or low RFI selection line based on their own phenotypic RFI values and stayed in these lines throughout the study. Among other areas that were compared, the studied found no significant difference in PREG, calving rate, weaning rate, calf weaning weight, CD, calf birth weight, and FSC. The only significant differences between the high and low RFI selection lines were a tendency for low RFI selection cows to calve later in the calving season ($P < .10$, mean = 5 days).

A second study by Basarab et al. (2007), included 222 calves and 136 dams of Angus-Hereford and Charolais Maine Anjou descent. Dams were classified into high, medium, and low groups based on RFI of progeny. Feed efficiency was measured by using a GrowSafe® system. Results from this research showed the low RFI progeny consumed less feed that the inefficient RFI animals and also had a better feed to gain ratio. Cows in this study were not artificial inseminated but were naturally serviced in the pasture. Cows that had low, medium, and high RFI calves had similar pregnancy, calving and weaning rates. A significant observation in this study was that dams that produced low RFI dams calved later in the year ($P < 0.001$) (Mean = 5 – 6 days). Basarab et al. (2007) also found that there was an increase in the number a twins associated with the high RFI group. The high RFI group was associated with a higher calf death loss percentage versus the low and medium RFI groups. Both Arthur et al. (2005), and Basarab et al. (2007) found that efficient RFI animals calved later in the calving season.

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Chapter 2 - Relationship between Feed Efficiency and Reproductive Measurements in Beef Cattle

Introduction

Today's beef cattle industry is constantly impacted by the price of feed. Selecting animals that are more feed efficient can save producers money in the cattle industry. Several traits estimate feed efficiency and are moderately heritable as measures of feed efficiency. Residual feed intake (RFI) has become a highly discussed topic during the last 10 years, although it has been around for much longer. RFI was defined in 1963 by Koch et al.. Other measures of feed efficiency include feed to gain ratio (F:G) and daily dry matter intake.(DMI). Reproduction is economically important in the cow-calf industry. Profit for a producer often comes from the number of calves sold, relative to the number of cows maintained.

Residual feed intake can be calculated by measuring an animal's actual feed intake and estimating what the animal should be eating based on gain and production. RFI is determined by subtracting expected feed intake from actual feed intake. An efficient RFI animal will eat less than what is estimated for them, resulting in a negative number. An inefficient RFI animal's calculation will be positive because the animal consumes more than what is expected. Selection for DMI doesn't necessarily identify an efficient animal because it does not account for the output of the animal. When selecting for decreasing F:G, it is impossible to know if intake is decreasing or if gain is increasing.

There has been little research in the area of relating feed efficiency and reproductive performance. Reproductive performance of females that were categorized by their phenotypic RFI values were previously measured by Basarab et al. (2007) and found that dams that produced low RFI calves calved later in the year (P<0.001) (5-6 days). Another study by Arthur et al. (2005) also found no difference between high and low RFI dams for pregnancy rate, calving rate, or calf birth weight. This study found a tendency of calves sired by low RFI cows to be born later in the calving season.

The objective of this study was to determine the relationship between feed efficiency measured in developing heifers and their future reproductive performance.

Materials and Methods

A total of 136 Angus-based females from the Kansas State University commercial cow herd over 5 years were used in this study and were identified as data set 1. All heifers were sired by bulls selected for high or low RFI EBV calculated by the Australian Angus Association (Table 1).There were 26 2004-born heifers and 50 2005-born heifers tested for feed intake at Kansas State University facilities using Calan Gates (Northwood, New Hampshire). 2007-born heifers (n=47) were tested at Green Springs, Missouri using a Grow Safe® (Airdrie, Alberta, Canada) system. In 2009, reproductive traits were measured on 13 heifers; however they were not tested for feed intake. Details concerning the ration and methods of testing can be found in a previous publication by Bormann et al, (2010).

Data set 2 consisted of 56 registered Hereford heifers from MM Herefords, Chanute, Kansas, born in 2006. The heifers were also tested for feed intake in 2007. All heifers received the same breeding treatment and were all managed the same. Heifers were bred in 2007 for a 2008 fall calving season.

Reproductive traits were collected in Angus dataset for each of the calving seasons that the dam remained in the herd. Reasons for culling included; infertility, failure to produce an AI-bred calf or health reasons. Calving data was collected on all parities that the dams were in the herd. Five parities were collected on 2004 heifers, 4 parities on 2006 heifers, 3 parities on 2007 and 1 parity on 2009 heifers, although not all dams in each group remained in the herd for all possible parities.

Heifer breeding contemporary group definition for dataset 1 included year, intake test group, and breeding treatment (estrus synchronization protocol). Later parity contemporary group definition included year and breeding treatment. All females were bred for a spring calving season ranging from February to May. Females were bred once by artificial insemination, then turned out to pasture with multiple bulls. First service conception was determined 30 days after artificial insemination. The females were diagnosed pregnant by ultrasonography from a single technician. If ultrasonography was not available, first service conception was determined by palpation results and calving date. Rectal palpation was done in the fall to diagnose pregnancy status of all females.

Reproductive measurements that were collected for each parity in both datasets included: pregnancy diagnosis (PREG), pregnancy type (PREGTYPE), first service conception (FSC), calf produced (CALVED), calving day within the season (CD) and the age that the heifer first calves in days (AFC). PREG was a binomial trait, with dams receiving a score of 1 if pregnant or a 2 if open at the fall palpation pregnancy check. PREGTYPE was scored as a 1 if pregnant by AI service, 2 if pregnant by natural service, or a 3 if open. FSC was scored a 1 pregnant to the AI service at the 30-35 day ultrasonography pregnancy check or a 2 if open at that time. CALVED was a binomial trait and was scored as a 1 if the dam produced a live calf or a 2 if she did not. The first calf born for the season was given a 1 for CD. Each calf born after that date received a value according to the days subsequent to the first calf. Open females were assigned a calving date of 21-d greater than the latest calving female in that contemporary group, by the method of Donoghue et al. (2004).

All analyses were performed with SAS (Cary, North Carolina). LSMeans for RFI, F:G, and DMI for heifers that differed for in PREG, PREGTYPE, FSC, and CALVED in all parities were determined with a general linear model. Contemporary group was a fixed effect in all models. If service sire was significant, it was included as a fixed effect also. The relationship between CD in all parities and AFC and the efficiency traits were determined by regression with contemporary group and service sire (if significant) as fixed effects. A chi-square test was used to determine if there were differences between sire RFI groups for the binomial traits of PREG, PREGTYPE, FSC, and CALVE in all parities. CD was also analyzed as a repeated measure over multiple parities using a mixed model, with female as a random effect, year and breeding treatment as fixed effects and RFI as a covariate.

Results

LSMeans for RFI, F:G and DMI for females that differed in PREG, FIRSTSERV, PREGTYPE, and CALVED for dataset 1 are shown in Tables 2-5. There were no significant differences in RFI when comparing pregnant or open females (Table 2). Feed to gain ratio did not significantly differ for parity 1-5. Daily dry matter intake did not differ when comparing pregnancy diagnosis for parity 1-4. Parity 5 showed that pregnant females had a significantly higher feed intake than open females (Table 2).

First service pregnancy rate did not have any significant difference in RFI in parities 1-4. Parity 5 showed that cows pregnant to first service had lower RFI females open to first service (Table 3). There was no significant difference in F:G for first service pregnancy for parity 1 or parities 3-5. Open females to first service in parity 2 had higher F:G than pregnant cows (Table 3). There was no significant difference in DMI for first service conception rates for parities 1-4. In parity 5 females open to first service had significantly higher DMI than pregnant females (Table 3).

There was no significant difference in RFI, DMI, or F:G in parities 1 and 3-5 for PREGTYPE (Table 4). There was a significant difference in F:G for parity 2 between PREGTYPE; AI being the most efficient animals, natural bred being intermediate and open females the least efficient. There was no significant difference in RFI, F:G, or DMI for CALVED (Table 5).

The regressions of CD and AFC on RFI, F:G, and DMI intake are shown in Table 6. There was no significant relationship between RFI, F:G, or DMI and AFC or CD for all parities (Table 6).

There was no significant difference between females sired by high or low RFI EBV bulls for AFC or CD in all parities (Table 7), however, there was a tendency for cows sired by efficient RFI EBV bulls to calve later than cows sired by inefficient RFI EBV bulls in parity 3.

PREG, FSC, PREGTYPE and CALVED for efficient and inefficient sire groups are shown in Tables 8-11. There were no differences between sire groups for PREG, FSC, or PREGTYPE. Females sired by efficient RFI bulls had a higher calving rate in parity 2, and tended to have a lower calving rate in parity 1 (Table 11).

When CD was analyzed as a repeated record, RFI was not an indicator of difference in CD (P = 0.5139). There was also no difference in CD between sire groups for CD with efficient sires having an LSMean of 35.64 d and the inefficient sires having an LSMean of 34.23 d (P = 0.789).

In the single calving season of dataset 2 (Hereford), RFI was not an indicator of difference in CD with a p-value of 0.774. There was also no difference in RFI between pregnant and open females with pregnant females having an LSMean of 0.11 kg and the open females having an LSMean of 0.14 kg (P = 0.869).

Discussion

When comparing the female's RFI, F:G and DMI and their reproductive performance, there were no differences in values between PREG, FSC, PREGTYPE, and CALVE for first parity heifers. There was no significant difference in RFI and DMI for PREG, FSC, PREGTYPE, and CALVED in parity two. However, in parity 2, there was a significant difference in F:G between females that were pregnant or open to first service (P = 0.053), and a significant difference in F:G between animals that were pregnant to AI or natural service (P = 0.014). In both cases, open females were less efficient then the pregnant females. The second parity of a female can often be important indicator for further productivity in the herd. In the first parity, the female is at her most fertile stage in life. The second parity can prove whether or not the female is capable of being pregnant past that very fertile stage. Being able to become pregnant at the second parity may indicate that she is able to become bred in subsequent breeding seasons. Being that PREG, FIRSTSERV, and PREGTYPE showed a tendency or significance for pregnant and AI bred females to have more efficient feed to gain ratios in parity two, this could mean that by selecting for better feed to gain ratios you could have females that could potentially stay in the herd longer and have an increase in pregnancy rates within the second parity.

In the third and fourth parities there were no differences in feed efficiency measurements and PREG, FSC, PREGTYPE, and CALVED. No differences could be found possibly because cows that had less than desirable reproductive performance had already been culled from the herd prior to these breeding seasons.

In the fifth parity, females that were open to first service had less efficient DMI (P <0.001) and RFI (P = 0.052) compared to females that were pregnant to first service. However, females that were pregnant to the fall pregnancy check were had higher DMI (P <0.001) than females that were open. It should be noted however, that there were only 9 animals within that analysis group. This could possibly question the accuracy of the significance shown.

There were similarities and contrast present between this study and the previous studies by Basarab et al. (2007) and Arthur et al. (2005). Those investigators also found no difference in calving rate and pregnancy rate. Arthur et al. (2005) also analyzed first-service conception and found no difference.

There were also no differences between sire groups for percentages of PREG, FSC, and PREGTYPE, except that efficient sired dams tended to have higher calving percentages in the second parity (P= 0.048). This again could prove that females bred to be more efficient could produce more calves past the initial fertile first season.

This study found there to be no relationship between RFI, F:G and DMI and AFC and CD in parities 1-2 and 4-5. Arthur et al. (2005) and Basarab et al. (2007) found that low RFI cows to calved or tended to calve later in the season by about 5 days, this study found no relationship between phenotypic measures of efficiency and CD for parities 1,2,4, and 5. However is in parity 3 there was a tendency for an increase in calving days (0.5 days) for every 1 kg increase in F:G ratio. In other words, less efficient feed to gain ratios resulted in calving later in the season, which is similar to results reported by Arthur et al (2005) and Basarab et al. (2007). Due to the fact that all three studies have fairly low numbers of females it is hard to identify any clear connection between feed efficiency and CD. A study involving many more animals is crucial.

When CD was analyzed as a repeated trait, there relationship with phenotypic measures of efficiency. When females were analyzed for CD based on their sire groups, no differences between sire groups were found for parities 1,2,4,5. However, in parity 3, efficiently sired females tended to calve later in the season by about 6 days. This result is similiar to what Basarab et al. (2007) and Arthur et al. (2005) both found.

The last dataset analyzed was the dataset containing the Hereford heifers. No differences resulted when comparing RFI and their reproductive performance. This set included less than half in number of what the other studies did and in return could have affected the results in this study.

Implications

Since the results of this study contradict results from other studies it is essential for further research to be done in the area to clearly identify any positive or negative relationships that reproduction may have with feed efficiency. Verified relationships would give producers proper knowledge to decide if and at what strength feed efficiency and reproduction would be added to their herd’s breeding plan.

Tables

Table 1. Sire residual feed intake group (I = inefficient, E = efficient), residual feed intake estimated breeding value (EBV) (kg) from the Australian Angus Association, and number of daughters in crossbred Angus females

Sire	Sire group	EBV	Daughters
1	I	0.29	18
2	I	0.26	10
3	I	0.30	3
4	I	0.31	27
5	I	0.19	4
6	E	-0.54	8
7	E	-0.72	14
8	E	-0.41	10
9	E	-0.51	14

Table 2. LSMeans for residual feed intake (RFI) (kg), feed to gain ratio (F:G) (kg), and daily dry matter intake (DMI) (kg) for heifers that were pregnant (PREG) or open at fall pregnancy check in crossbred Angus females

		RFI			F:G			DMI		
Parity	n	PREG	OPEN	P	PREG	OPEN	P	PREG	OPEN	P
1	99	-0.11	0.02	0.7377	12.41	14.30	0.5795	11.28	11.46	0.6403
2	63	-0.15	0.34	0.4605	8.18	12.29	0.5196	10.39	10.86	0.4375
3	53	0.15	0.30	0.8817	10.52	15.97	0.4780	10.34	10.03	0.6727
4	28	-0.50	-0.12	0.6320	9.95	7.82	0.4471	9.98	10.14	0.8037
5	9	0.05	-0.45	0.4027	11.28	8.68	0.6882	8.82	8.03	0.0002

Table 3. LSMeans for residual feed intake (RFI) (kg), feed to gain ratio (F:G), and daily dry matter intake (DMI) (kg) for dams that were pregnant (PREG) or open to first service conception in crossbred Angus females

		RFI			F:G			DMI		
Parity	n	PREG	OPEN	P	PREG	OPEN	P	PREG	OPEN	P
1	99	-0.22	0.05	0.3803	11.94	15.62	0.1637	11.10	11.38	0.3326
2	66	0.02	-0.37	0.4030	2.73	7.00	0.0534	10.36	10.60	0.4849
3	53	-0.18	0.38	0.3502	6.71	12.92	0.1501	10.48	10.24	0.5435
4	28	-0.57	-0.44	0.7947	6.92	9.02	0.2234	9.96	10.00	0.9251
5	9	-0.46	0.22	0.0524	8.29	12.34	0.3340	8.26	9.02	0.0002

Table 4. LSMeans for residual feed intake (RFI) (kg), feed to gain ratio (F:G), and daily dry matter intake (DMI) (kg) for dams that produced AI-bred calves (A), naturally-bred calves (N) or were open (O) in crossbred Angus females

		RFI				F:G				DMI			
Parity	n	A	N	O	P	A	N	O	P	A	N	O	P
1	99	-0.12	-0.09	0.01	0.9511	11.52	13.56	13.59	0.7053	11.27	11.24	11.20	0.9802
2	67	-0.06	-0.10	-0.77	0.5158	4.69	11.78	18.34	0.0140	10.34	10.54	10.78	0.6519
3	53	-0.18	0.38	0.34	0.6493	6.71	12.71	14.22	0.3506	10.48	10.28	9.99	0.7582
4	28	-0.40	-0.58	-0.10	0.8523	8.46	8.18	6.49	0.7997	10.01	9.95	10.15	0.9625
5	9	-0.47	0.12	.	0.1619	8.09	11.81	.	0.4395	8.93	8.63	.	0.1251

Table 5. LSMeans for residual feed intake (RFI) (kg), feed to gain ratio (F:G) (kg), and daily dry matter intake (DMI) for dams that produced a calf(CALVED) or not (NOT) in crossbred Angus females

		RFI			F:G			DMI		
Parity	n	CALVED	NOT	P	CALVED	NOT	P	CALVED	NOT	P
1	124	-0.11	0.02	0.6516	12.46	12.31	0.9481	10.51	10.54	0.9230
2	70	-0.06	-0.69	0.1998	9.10	12.68	0.4004	10.42	10.54	0.7749
3	53	-0.23	-0.22	0.9890	10.53	12.90	0.6611	10.37	10.06	0.5317
4	13	-0.05	0.41	0.2717	9.15	9.84	0.6986	9.35	9.77	0.5815
5	9	-0.05	0.05	0.7725	8.78	16.47	0.7587	8.66	8.56	0.5222

Table 6. Regression coefficients (b) for the regression of age at first calving (AFC) and calving day (CD) for five parities on residual feed intake (RFI), feed to gain ratio (F:G) and daily dry matter intake (DMI) in crossbred Angus females

	RFI		F:G		DMI	
	b	P-Value	b	P-Value	b	P-Value
AFC	0.8323	0.6643	0.1755	0.4651	1.0221	0.5478
CD- Parity1	1.5104	0.3871	0.1753	0.3936	0.4856	0.8060
CD- Parity2	-2.8486	0.2298	0.3796	0.1335	1.8525	0.5223
CD- Parity3	0.3699	0.8904	0.5254	0.0952	-4.1811	0.2487
CD- Parity4	4.744	0.3311	0.2001	0.9167	4.8581	0.3004
CD- Parity5	17.5378	0.1964	1.4646	0.2544	-29.9817	0.4639

Table 7. LSMeans for Age at first calving (AFC) (days) and Calving Day (CD) (days) for females sired by efficient (E) or inefficient (I) residual feed intake EBV bulls in crossbred Angus females

Parity	n=	LSMeans		P-values
		E	I	
AFC	121	759.14	758.00	0.8353
CD1	120	35.48	30.95	0.3621
CD2	62	25.88	37.25	0.1261
CD3	48	43.52	37.29	0.0964
CD4	22	29.99	44.77	0.5703
CD5	6	32.00	37.25	0.8032

Table 8. Total number of females exposed for breeding and percentage pregnant that were sired by efficient (E) and inefficient (I) residual feed intake EBV bulls that were pregnant (PREG) at the end of the breeding season in crossbred Angus females

Parity	E		I		P-Values
	n	Preg	n	Preg	
1	46	80.43	57	82.46	0.7926
2	26	88.46	36	94.12	0.4322
3	21	85.71	26	96.15	0.2028
4	10	90.00	12	91.67	0.8923
5	1	100.00	4	100.00	1.0000

Table 9. Total number of females exposed for breeding and percentage pregnant to first service conception that were sired by efficient (E) and inefficient (I) residual feed intake EBV bulls that were pregnant to first AI service (FSC) in crossbred Angus females

Parity	E		I		P-Values
	n	FSC	n	FSC	
1	46	52.17	57	52.63	0.9631
2	26	46.15	34	61.76	0.2284
3	21	28.57	26	34.62	0.6578
4	10	40.00	12	25.00	0.4520
5	1	0	4	25.00	0.5762

Table 10. Total number of females exposed for breeding and percentage of pregnancy types that were sired by efficient (E) and inefficient (I) residual feed intake EBV bulls that were pregnant to AI (A) or natural service (N) in crossbred Angus females

Parity	E			I			P-Values
	n	A	N	n	A	N	
1	42	35.17	42.86	57	43.86	36.84	0.7141
2	26	53.85	38.46	35	54.29	25.71	0.3150
3	21	28.57	52.38	26	34.62	61.54	0.2434
4	10	40.00	50.00	12	33.33	58.33	0.9265
5	1	0	10.00	4	25.00	75.00	0.5762

Table 11. Total number of females exposed for breeding and percentage calved that were sired by efficient (E) and inefficient (I) residual feed intake EBV bulls that calved in crossbred Angus females

Parity	E		I		P-Values
	n	Calved	n	Calved	
1	56	58.93	65	73.85	0.0820
2	26	92.31	36	72.22	0.0482
3	21	80.95	26	80.77	0.9873
4	10	80.00	12	91.67	0.4261
5	2	100.00	4	50.00	0.2207

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