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INTRODUCTION

Supplemental nutrition for cattle is the greatest operating cost for cow-calf producers, accounting for 65% of the annual expenses (Meyer et al., 2008). Therefore, selection pressure for efficient animals that have lower feed intake but maintain production, or average intake with higher production, could have positive impacts on cow–calf profitability (Meyer et al., 2008). Thus, improving feed efficiency through genetic selection holds significant opportunity for the beef industry.

Residual feed intake (RFI) is currently being used as a selection tool for purchasing and retaining heifers and for selecting bulls and semen. Most studies have used steers and terminal heifers when evaluating RFI impact on various aspects of beef cattle production (Kelly et al., 2010). Additionally, the majority of RFI studies have included energy-dense diets and rations focusing on feedlot performance (Lawrence et al., 2011). However, the use and relevance of RFI as a selection tool for the commercial cow–calf industry needs further research (Manafiazar et al., 2015).

Research pertaining to RFI of cattle offered forage-based diets is limited (Arthur et al., 2005), with even fewer data available related to beef cattle forage-based production systems (Meyer et al., 2008). As a result, more research is needed to evaluate the utility of RFI estimates on the beef production in extensive forage base systems (Kenny et al., 2018). Therefore, the objectives of this study were to evaluate the influence of heifer postweaning RFI and cow age on dry matter intake (DMI), intake behavior, as well as milk production of dry-lotted black Angus beef cows. We hypothesized that heifers identified as low RFI eat less and the influence of RFI may interact with cow age.

MATERIALS AND METHODS

The use of animals in this study was approved by the Agricultural Animal Care and Use Committee of Montana State University AACUC #2018-AA12. These studies were conducted at the Northern Agricultural Research Center, located in Havre, Montana.

Heifer RFI Trials

Starting in 2008 to present, all cattle were utilized in a heifer RFI trial for a minimum of 77 d on a forage-based ration provided in a GrowSafe system (GrowSafe DAQ 4000E; GrowSafe System Ltd., Airdrie, AB, Canada). All heifers had free access to 18 GrowSafe feed bunks and ad libitum access to water and forage-based diets, consisting of 30.4% corn silage, 41.1% grass hay, and 28.5% alfalfa on a dry mater basis, formulated to meet maintenance requirement for growing moderate frame beef heifers (10.5% crude protein and 66.0% total digestible nutrients; NASEM, Beef Cow Requirements, 2016). Individual heifer

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postweaning RFI was calculated following the parameters set forth by Archer et al. (1997) and Arthur et al. (2001). Heifers were categorized as either low (> −0.50 SD from mean) or high (< +0.50 SD from the mean) within year (Parsons et al., 2021).

Two feed intake studies were conducted to evaluate the impacts of heifer postweaning RFI on differing ages and stages of beef cattle production. Individual body weights (BW) and body condition scores (BCS) were recorded and cattle placed in a GrowSafe feeding system for DMI analysis. For each study, treatments were replicated in two pens, each containing 16 Growsafe feeding units. Cows were provided a 7-d acclimation period followed by 14-d DMI intake recording period. Seven of the highest accuracy days of DMI recordings were used to calculate average DMI per individual animal following each DMI study.

Study 1: Nonlactating Pregnant Cow DMI

Fifty-nine nonlactating, pregnant, black Angus females were utilized to evaluate the impacts of heifer postweaning RFI on DMI postweaning. All cows were fed commercially available free-choice alfalfa/straw pellet formulated to meet requirements for nonlactating, pregnant cows (Table 1; CHS Nutrition, Sioux Falls, SD). At the initiation of the trial (14-d postweaning), cows were classified by age (2/3, 5/6, and 8/9 yr old; Table 2), and within-age class represented both low and high RFI and dry-lotted for 16 h to obtain uniform shrunk BW.

Table 1. Ingredients and nutrient composition (DM basis) of the commercially available hay pellets provided ad libitum to cows in GrowSafe pens during the 21-d DMI trials, fall 2019 and spring 2020

Item	Nonlactating, pregnant cow	Lactating, non-pregnant cow
Ingredient	%	%
Alfalfa hay	49.53	79.05
Straw	49.52	
Corn, ground		20.0
Ultramin 12-6	0.75	0.75
Trace mineral mix	0.20	0.20
Nutrient value		
DM	90.4	93.6
CP	16.8	10.5
ADF	34.0	40.4
TDN	65.1	62.0

Study 2: Lactating Nonpregnant Cow DMI and Milk Production

Fifty-four lactating, nonpregnant, black Angus females were utilized to evaluate the impacts of heifer postweaning RFI (low and high) and cow age (3/4, 6/7, and 9/10 yr cows) and dry-lotted for 16 h to obtain uniform shrunk BW. Cows were selected by same age and RFI criteria as described for Study 1. However, for this study, we only utilized cows that calved within the first 42 d of the calving period, focusing on artificial insemination–conceived calves. On average, the intake study was conducted from day 40 to day 60 postpartum. All cows were fed commercially available free-choice alfalfa/grass pellet formulated to meet requirements for lactating cows (NASEM, Beef Cow Requirements, 2016). Following the DMI trial, a weigh-suckle-weigh trial was conducted to evaluate the impacts of heifer postweaning RFI and cow age on milk production following methods detailed by Williams et al. (1979).

Statistical Analysis

For both Study 1 and 2, the influence of RFI and cow age on initial cow BCS and BW was analyzed using ANOVA with a generalized linear model including RFI, cow age, and the interactions of RFI and cow age as fixed effects. Additionally, the influence of RFI and cow age on intake and intake behavior was analyzed using ANOVA with a generalized linear mixed model including individual cow and pen as random effects. Individual animal was considered the experimental unit, and an alpha ≤ 0.05 was considered significant. Orthogonal polynomial contrasts were used to determine linear and quadratic effects for cow age. Means were separated using the Tukey method when $P < 0.05$. Tendencies were reported when significance was $P \leq 0.10$. All statistical analyses were performed in R (R Core Team, 2020).

RESULTS

Study 1: Nonlactating Pregnant Cow DMI

Cow BW displayed a cow age × RFI interaction ($P < 0.01$) with 5/6-yr-old low RFI cows having a lighter BW than high RFI cows (Table 2). Cow BCS also displayed a cow age × RFI interaction ($P = 0.02$) where low RFI 5/6-yr-old cows had lower BCS than high RFI cows. Both cow DMI intake (kg/d) and intake rate (g/min) displayed a cow age effect ($P < 0.01$) with increasing DMI and intake rate with increasing cow age. Neither DMI (g/

kg BW), % CV, nor time spent at the feeder (min/d) was effected by cow age, RFI, or cow age × RFI ($P > 0.16$).

Study 2: Lactating Nonpregnant Cow DMI

Cow BW displayed a cow age × RFI interaction ($P < 0.01$), with low RFI 6/7-yr-old cows having a lighter BW than high RFI cows, and low RFI 9/10-yr-old cows having a higher BW than high RFI cows (Table 3). Similar to cow BW, cow BCS displayed a cow age × RFI interaction ($P < 0.01$) where low RFI 6/7-yr-old cows had lower BCS than high RFI cows, whereas low RFI 9/10-yr-old cows had higher BCS than low RFI cows. Calf BW, measured at weigh-suckle-weigh, displayed a cow age × RFI interaction ($P < 0.03$), where calf BW from 3/4-yr-old cows were lower in high RFI cows compared with low RFI cows (Table 3).

Cow DMI (kg/d) displayed a cow age effect ($P < 0.01$) with a quadratic increase in DMI with increasing cow age ($P < 0.01$; Table 3). Similarly,

Table 2. Cow body weight (BW) and body condition scores (BCS) of three age classes of nonlactating, pregnant beef cows (Study 1)

	Cow age, yr							*P*-value		
	2/3		5/6		8/9					
Category	Low RFI	High RFI	Low RFI	High RFI	Low RFI	High RFI	SE[1]	Age	RFI	Age × RFI
Cows, *n*	10	10	10	10	10	9				
Cow BW[2]	435.2	444.1	470.2[a]	497.4[b]	567.7	557.9	4.66	<0.01	0.17	<0.01
Cow BCS[3]	5.38	5.45	5.43[a]	5.65[b]	5.38	5.28	0.06	<0.01	0.35	0.02
DMI, kg/d	12.86	12.58	15.15	17.07	16.59	16.59	0.10	<0.01	0.77	0.21
DMI, g/kg BW	29.57	28.24	26.63	28.69	29.35	30.22	1.68	0.57	0.48	0.43
DMI, g/min	92.24	92.60	145.88	144.83	135.04	132.45	7.95	<0.01	0.97	0.98
% CV	15.95	22.41	22.50	17.76	16.53	20.67	3.37	0.62	0.16	0.21
Time @ feeder, min/d	144.65	139.92	105.39	123.12	131.69	132.28	9.51	0.45	0.67	0.44

[1]Pooled standard error of the means.

[2]Cow body weight (kg) at initiation of trial.

[3]Cow body condition score at initiation of trial.

Table 3. The influence of heifer postweaning RFI classification on subsequent beef cow performance and dry matter intake behavior of three age classes of lactating, nonpregnant beef cows average 60-d postpartum (Study 2)

	Cow age, yr							*P*-value		
	3/4		6/7		9/10					
Category	Low RFI	High RFI	Low RFI	High RFI	Low RFI	High RFI	SE[1]	Age	RFI	Age × RFI
Cows, *n*	7	10	9	10	9	9				
Cow BW[2]	397.5	408.4	541.8[a]	476.7[b]	534.2[a]	516.8[b]	4.96	<0.01	0.12	<0.01
Cow BCS[3]	4.22	4.19	4.75[a]	4.95[b]	4.72[a]	4.50[b]	0.05	<0.01	0.69	<0.01
Calf, *n*	6	10	9	10	9	9				
Calf BW[4]	97.3[a]	91.9[b]	95.1	97.9	104.9	101.8	1.55	<0.01	<0.02	<0.03
Calf Julian birth date	70.2	66.8	75.5	73.4	76.1	76.6	1.41	<0.01	0.09	0.38
DMI, kg/d	18.22	18.41	22.90	24.00	23.84	23.10	1.00	<0.01	0.88	0.57
DMI, g/kg BW	45.74	44.88	42.48	41.71	45.00	45.19	1.87	0.32	0.74	0.95
DMI, g/min	127.70	123.71	166.33	162.48	168.58	163.12	11.58	0.02	0.81	0.99
% CV	13.25	12.91	9.01	11.17	12.54	11.49	1.46	0.68	0.88	0.45
Time @ feeder, min/d	149.42	154.30	140.00	153.07	149.28	152.41	11.99	0.99	0.75	0.88
Milk production, kg	3.89[a]	2.77[b]	4.88[a]	4.22[b]	4.23	4.28	0.16	<0.01	<0.01	<0.01
Milk production, g/kg BW	9.76[a]	6.82[b]	9.17[a]	7.32[b]	8.04	8.42	0.38	<0.01	<0.01	<0.01

[1]Pooled standard error of the means.

[2]Cow body weight (kg) at initiation of trial.

[3]Cow body condition score at initiation of trial.

[4]Calf body weight (kg) at weigh-suckle-weigh.

intake rate (g/min) displayed a cow age effect ($P < 0.02$) with a linear increase ($P < 0.01$) in intake rate with increasing cow age. Neither DMI intake (g/kg BW), % CV, nor time spent at the feeder (min/d) was effected by cow age, or RFI, averaging 21.7 g/kg BW, 11.7% CV, and 149.7 min/d, respectively.

Cow milk production (kg) displayed a cow age × RFI interaction ($P < 0.01$; Table 3), with 3/4- and 6/7-yr-old low RFI cows producing more milk than high RFI cows. In addition, cow milk production (g/kg BW), displayed a cow age × RFI interaction ($P < 0.01$) with 3/4- and 6/7-yr-old low RFI cows producing more milk per kg of BW than high RFI cows; however, no differences were observed in 9/10-yr-old cows ($P = 0.48$).

DISCUSSION

It has been reported that as cattle grow and mature, composition of their gain changes from protein accretion to fat deposition (Trenkle and Willham, 1977). Since the expense of protein accrual is less than for fat deposition, the efficiency that cattle convert feed into BW gain is reduced as they mature (Ferrell and Jenkins, 1985). Previous research has reported the changes in feed efficiency (RFI) of cattle at different stages of physiological growth. Durunna et al. (2012) reported that following two consecutive 70-d RFI periods, 49% of the heifers maintained their original RFI, whereas 51% had a different RFI, indicating reranking exists in heifers despite receiving the same basal diet. Loyd et al. (2011) suggested that RFI determined during the prepubertal period may only be a moderate predictor of postpubertal RFI.

Archer et al. (2002) reported a moderate correlation of 0.40 between RFI measured in heifer postweaning and later as nongestating, nonlactating 3-yr-old cows. Freetly et al. (2020) compared the RFI of yearling heifers following an 84-d RFI intake trial with subsequent RFI of 5-yr-old nonpregnant, nonlactating cows and reported that feed intake and average daily gain are heritable and genetically correlated between heifers and cows. Black et al. (2013) compared the RFI of growing heifers following a 70-d RFI trial and subsequently as 3-yr-old lactating beef cows and reported that heifers that were the most feed efficient subsequently consumed less feed as lactating cows while maintaining similar performance. However, they reported that correlations between heifer and mature lactating cow RFI values were not significant, indicating that within-animal feed efficiency was not maintained as the calves developed from growing heifers to mature, lactating cows.

Results from our research are in general agreement with previous research where feed efficiency tends to change between physiological ages and stages of production of female beef cows, indicating that heifer postweaning RFI may not be a reliable predictor of mature cow feed efficiency. Cow milk production was affected by both cow age and RFI with 3/4- and 6/7-yr-old low RFI cows producing more milk than high RFI cows. Most of the effects associated with our research were directly related to either cow age or an interaction between RFI and cow age.

Conflict of interest statement. None declared.

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