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Efficiency of beef breeding cows that vary in live weight and milking potential

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Abstract

Size and milking potential of beef breeding cows affect their productivity and efficiency. This experiment compared the productivity and efficiency of straightbred Angus (AA) (high live weight, low-milk potential), Angus-cross-Holstein Friesian (AF) (high live weight, high-milk potential), Angus-cross-Kiwicross (AK) (moderate live weight, high-milk potential) and Angus-cross-Jersey (AJ) cows (low live weight, high-milk potential). High-milk lines produced heavier calves at weaning than the low-milk-producing AA. AF and AK cows weaned the heaviest calves at 225 ± 3 kg and 224 ± 4 kg respectively. These calves were heavier than those weaned by AJ cows (212 ± 3 kg). All of these three genotypes weaned heavier calves than AA cows (197 ± 3 kg). In turn, all three high-milk lines had greater weaning efficiency ((weaning weight of calf/weight of cow at calf weaning) x100) than AA cows which had an efficiency of 36.7 ± 0.7%. AJ and AK cows were the most efficient at 46.7 ± 0.7% and 46.0 ± 1.0%, respectively. AJ cows were also more efficient than the AF cows (44.0 ± 0.8%). Increased milking potential and decreased live weight of breeding cows increased their efficiency of production.

Keywords: beef; efficiency; size; milk yield

Introduction

Beef breeding cow herds are often used to complement other livestock on New Zealand farms. Their role is largely to maintain pasture quality, benefiting these other classes. They are often farmed on hill country and their feed supply can vary widely throughout the year so the beef cow's ability to use live weight as a buffer when feed is low, yet remain productive, is essential. The biological efficiency of the beef breeding cow is low compared to that of other domestic livestock (Morris et al. 1994) due to a relatively low reproductive rate and a loss of energy at each stage of the conversion of grass to milk to calf growth.

A beef cow's efficiency is determined by the ratio of output (kg of weaned calf) to input (feed eaten). The weaning weight of the calf depends on genes, milk supply and environmental factors. Feed eaten depends on cow live weight and amount of milk produced.

Cow live weight is often used as a proxy to estimate maintenance feed requirements, and therefore, the intake of the animals. Maintenance costs contribute to between 70 and 75% of the total feed requirements (Ferrell & Jenkins 1985). High maintenance costs are thus a major contributing factor to inefficiency in beef breeding cow systems. The question of optimal cow size of beef cattle has been debated for many years because feed costs are the major expense in beef cattle production.

Previous work identified that cows that were lighter (Webby & Thomson 1994), or produced more milk (Cundiff et al. 2007) were more efficient. This experiment was conducted to compare the performance at second parity of cows of differing sizes and milking potential when farmed under hill-country beef cattle conditions.

Materials and methods

Animals and treatments

Background. Four cow genotypes, differing in size and milking ability, were generated through contract matings of Angus, Holstein Friesian, Kiwicross and Jersey dams which were inseminated with semen from a team of four Angus bulls. The four resulting genotypes were: straightbred Angus (AA) (high live weight, low-milk potential); Angus-cross-Holstein Friesian (AF) (high live weight, high-milk potential); Angus-cross-Kiwicross (AK) (moderate live weight, high-milk potential); and Angus-cross-Jersey (AJ) (low live weight, high-milk potential). Dams of AK animals were between 4/16 and 12/16 Holstein Friesian, with the balance being Jersey genetics. Cows had their first calves at two years of age (Hickson et al. 2012a), in the spring of 2010.

Present experiment. At approximately 28 months of age on 8 December 2010, the first-lactation cows (AA, n = 51; AF, n = 36; AK, n = 24; AJ, n = 42) were introduced to either two Simmental or two Angus bulls at ratios between 1:19.5 and 1:27. The four mating herds were balanced for cow genotype so that similar numbers of calves from each sire-dam genotype combination could be expected. Angus bulls were selected for high Angus Pure Index (Breedplan 2013b), while Simmental bulls were selected for low calf birth weight and breed average 600-day weight (Breedplan 2013a). All cows were joined for nine weeks, and the 50 latest-calving cows remained with the bull for a total of ten weeks.

Cows that were diagnosed non-pregnant, or those that were diagnosed pregnant but did not calve (AA, n = 10; AF, n = 4; AK, n = 7; AJ, n = 3), were removed from the experiment, apart from for the

Table 1 Least square means ± standard error of the mean for cow live weight, rib fat depth and body condition score (Scale 1 = Emaciated to 10 = Obese) of straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Kiwicross (AK) and Angus-cross-Jersey (AJ) cows with a different potential for live weight and milk production. Winter = 14 June for live weight and 2 June for measurements; Pre-calving = 5 September; Pre-mating = 8 December; Weaning = 15 March.

Measurement	Time of measurement	Cow genotype			
		AA	AF	AK	AJ
Number of cows at start	Winter	40	31	16	39
	Pre-calving	40	31	16	39
	Pre-mating	37	28	16	36
	Weaning	37	27	16	36
Live weight (kg)	Winter	490 ± 6^{c}	480 ± 7^{bc}	465 ± 9^{b}	429 ± 6^{a}
	Pre-calving	506 ± 6^{c}	503 ± 7^{bc}	481 ± 9^{b}	449 ± 6^{a}
	Pre-mating	541 ± 7^{c}	524 ± 8^{bc}	500 ± 11^{b}	462 ± 7^{a}
	Weaning	542 ± 7^{c}	513 ± 8^{b}	491 ± 10^{b}	457 ± 7^{a}
Rib fat depth (mm)	Winter	3.7 ± 0.2^{b}	2.5 ± 0.2^{a}	2.3 ± 0.3^{a}	2.4 ± 0.2^{a}
	Pre-calving	2.9 ± 0.1^{b}	2.3 ± 0.1^{a}	2.4 ± 0.2^{a}	2.3 ± 0.1^{a}
	Pre-mating	3.5 ± 0.1^{b}	2.4 ± 0.2^{a}	2.4 ± 0.2^{a}	2.3 ± 0.1^{a}
	Weaning	3.8 ± 0.1^{b}	2.4 ± 0.2^{a}	2.4 ± 0.2^{a}	2.4 ± 0.1^{a}
Body condition score	Winter	5.2 ± 0.1^{c}	4.8 ± 0.1^{b}	4.7 ± 0.1^{ab}	4.5 ± 0.1^{a}
	Pre-calving	6.0 ± 0.1^{c}	5.1 ± 0.1^{b}	4.9 ± 0.1^{ab}	4.8 ± 0.1^{a}
	Pre-mating	6.2 ± 0.1^{c}	5.1 ± 0.1^{b}	4.9 ± 0.1^{ab}	4.8 ± 0.1^{a}
	Weaning	6.2 ± 0.1^{b}	4.8 ± 0.1^{a}	4.8 ± 0.2^{a}	4.7 ± 0.1^{a}

[abc]Values between columns within rows with different superscripts are significantly different ($P < 0.05$).

Table 2 Least squares means ± standard error of the mean for calf birth weight and calf birth weight as a proportion of maternal pre-calving live weight for straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Kiwicross (AK) and Angus-cross-Jersey (AJ) cows with a different potential for live weight and milk production.

Factor	Type	Number of cows	Calf birth weight (kg)	Calf birth weight/maternal pre-calving live weight (%)
Dam genotype				
	AA	40	34.7 ± 0.7	6.9 ± 0.2^{a}
	AF	31	35.8 ± 0.8	7.1 ± 0.2^{ab}
	AK	16	36.1 ± 1.2	7.6 ± 0.2^{b}
	AJ	38	33.6 ± 0.8	7.5 ± 0.2^{b}
Sire breed				
	Angus	60	34.7 ± 0.7	7.2 ± 0.2
	Simmental	65	35.4 ± 0.7	7.4 ± 0.1
Calf sex				
	Female	56	33.4 ± 0.7^{a}	7.0 ± 0.1^{a}
	Male	69	36.8 ± 0.6^{b}	7.6 ± 0.1^{b}

[ab]Values within columns and within factors with different superscripts are significantly different ($P < 0.05$).

analysis of weaning rate (calves weaned/cow joined). Calves were tagged, weighed, identified to dam, and sex was recorded within 24 hours of birth. Dams of dead calves were excluded from post-calving measurements and cows that gave birth to twins, (AA, n = 1; AF, n = 1; AK, n = 1) were excluded from the experiment. After calving, cows were allocated to one of three herds based on calving date, balanced by cow genotype and sire breed of calf. The now-second-lactation cows were joined with Charolais bulls for nine weeks, beginning on 8 December 2011 at ratios of either 1:17 or 1:24.5.

Measurements

Cows were weighed monthly, and had quarterly measurements recorded for body condition score (BCS) using DairyNZ's 1 to 10 scale where 1 = Emaciated and 10 = Obese (Roche et al. 2004) and rib-fat depth (via ultrasound to measure the depth of the subcutaneous fat over the *M. Logissimus* between the 12th and 13th rib) (Hickson et al. 2012b). Pregnancy diagnosis was carried out 16 weeks after the start of the joining period by trans-rectal ultrasound. A plasma sample was taken from live calves between 24 and 48 hours after birth to measure immunoglobulin G (IgG) concentration, gamma-glutamyltransferase (GGT) activity and total protein concentration in order to establish whether the calves had adequate colostrum intake. Adequate concentrations of IgG and protein were considered as >800 mg/dL (Whittum & Perino 1995) and >50g/L (Chigerwe & Tyler 2010), respectively. Adequate GGT activity was considered >200 U/L (Perino et al. 1993). Calves were weighed at birth and at weaning. Cow weaning efficiency was calculated as

$$\text{Efficiency} = \frac{\text{Weaning weight of calf (kg)}}{\text{Weight of cow at calf weaning (kg)}} \times 100$$

Table 3 Immunoglobulin G (IgG) concentration, gamma-glutamyltransferase (GGT) activity and protein concentration as indicators of colostrum intake for calves from straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Kiwicross (AK) and Angus-cross-Jersey (AJ) cows with a different potential for live weight and milk production. Calves were sired by either an Angus (A) or a Simmental (S) bull. Values are least squares means ± standard error of the mean or back-transformed means and 95% confidence intervals (in brackets). Dam genotype by sire breed interaction for IgG concentration and protein concentration were not significant.

Factor	Type	Number of cows	IgG (mg/dL)	GGT (IU/L)	Protein (g/L)
Dam genotype	AA	37	2217 ± 171	686 (494-909)^{a}	71.2 ± 1.8
	AF	28	2689 ± 196	1386 (1067-1747)^{b}	76.1 ± 2.1
	AK	15	2322 ± 268	1383 (958-1885)^{b}	72.3 ± 2.9
	AJ	36	2620 ± 172	1371 (1091-1683)^{b}	72.7 ± 1.8
Sire breed	Angus	56	2550 ± 161	1309 (1052-1594)	73.6 ± 1.7
	Simmental	60	2374 ± 151	1065 (848-1307)	72.6 ± 1.6
Interaction of dam genotype and sire breed	A x AA	16		889 (568-1282)^{ab}	
	A x AF	16		1921 (1426-2489)^{e}	
	A x AK	7		1044 (522-1745)^{acd}	
	A x AJ	17		1502 (1073-2002)^{cde}	
	S x AA	21		509 (299-774)^{a}	
	S x AF	12		938 (550-1430)^{ac}	
	S x AK	8		1770 (1129-2554)^{de}	
	S x AJ	19		1246 (883-1672)^{bcd}	
Calf sex	Female	52	2615 ± 148	1339 (1098-1604)	75.4 ± 1.6^{b}
	Male	64	2309 ± 135	1038 (846-1251)	70.8 ± 1.4^{a}

^{abcde}Values within columns and within factors with different superscripts are significantly different (P <0.05).

Table 4 Calf weaning weight, average daily live weight gain (ADG) of the calves from birth until weaning, weaning efficiency ratio measured as weaning weight of calf as a percentage of cow live weight at calf weaning and weaning rate calculated as the number of calves weaned per cow joined for straightbred Angus (AA), Angus-cross-Holstein Friesian (AF), Angus-cross-Kiwicross (AK) and Angus-cross-Jersey (AJ) cows with a different potential for live weight and milk production. Values are least squares means ± standard error of the mean or back-transformed means and 95% confidence intervals (in brackets).

Factor	Type	Number of cows	Calf weaning weight (kg)	ADG (kg/day)	Weaning efficiency (%)	Cows joined in 2010	Weaning rate (%)
Dam genotype	AA	37	197.2 ± 2.6^{a}	1.05 ± 0.01^{a}	36.7 ± 0.7^{a}	51	74.3 (60.3-84.7)
	AF	27	225.1 ± 3.1^{c}	1.21 ± 0.02^{c}	44.0 ± 0.8^{b}	36	80.0 (63.4-90.2)
	AK	16	224.1 ± 4.0^{c}	1.22 ± 0.02^{c}	46.0 ± 1.0^{bc}	24	69.6 (48.3-84.9)
	AJ	36	211.8 ± 2.6^{b}	1.16 ± 0.02^{b}	46.7 ± 0.7^{c}	42	86.4 (71.9-94.0)
Sire breed	Angus	55	210.3 ± 2.5^{a}	1.13 ± 0.01^{a}	42.2 ± 0.6^{a}	73	77.0 (65.5-85.6)
	Simmental	61	218.8 ± 2.3^{b}	1.18 ± 0.01^{b}	44.5 ± 0.6^{b}	80	79.5 (68.0-87.6)
Calf sex	Female	52	205.8 ± 2.3^{a}	1.11 ± 0.01^{a}	42.2 ± 0.6^{a}		
	Male	64	223.3 ± 2.1^{b}	1.20 ± 0.01^{b}	44.5 ± 0.5^{b}		

^{abc}Values within columns and within factors with different superscripts are significantly different (P <0.05).

Statistical methods

Statistical analysis was conducted using SAS (Version 9.2, SAS Institute Inc, Carey, North Carolina, USA). The variables, calf birth weight, average daily gain (ADG), calf weaning weight, calf serum total protein and IgG concentration, cow weaning efficiency, and calf birth weight as a proportion of cow pre-calving live weight, were all analysed using linear models. Calf serum GGT activity was not normally distributed and was analysed after the square root transformation. The variables of cow live weight, BCS and rib fat depth were analysed using mixed models allowing for repeated measures. The random effect of animal was included in the model for analysis of repeated measures. Weaning rate was analysed as a binomial variable with a logit transformation. All models included the fixed effects of cow genotype, breed of calf's sire, the interaction of cow genotype with breed of calf's sire, and sex of calf where appropriate.

Calf's date of birth was fitted as a covariate in the models for calf birth weight, ADG, weaning weight, IgG and protein concentrations and GGT activity in the serum samples, cow weaning efficiency and calf birth weight as a proportion of cow live weight. Assistance rate (number of calves assisted per calf born), survival rate (number of calves weaned per calf born), pregnancy rate (number of cows pregnant per cow joined), adequacy of IgG concentrations, protein concentrations and GGT activity were not analysed due to not all genotypes having both successful and unsuccessful outcomes. Raw values are presented where relevant.

Results

AA cows were heavier (P <0.05) than AK and AJ cows in winter, pre-calving and pre-mating, and were heavier than all other genotypes at weaning (Table 1). AJ cows were lightest throughout the year. AA cows had the greatest (P <0.05) rib-fat depth and BCS throughout the experiment. AF cows had greater (P <0.05) BCS than AJ cows at winter, pre-calving and pre-mating, but not at weaning.

There was no effect (P >0.05) of cow genotype on calf birth weight (Table 2). Female calves were on average lighter (P <0.05) than male calves at birth. Calf birth weight as a proportion of the cow's pre-calving live weight was greater (P <0.05) for AJ and AK than AA cows. Only two cows required assistance at calving: an AA cow mated to an Angus bull that had a female calf, and an AJ cow mated to a Simmental bull that had a male calf.

There was no effect (P >0.05) of cow genotype, breed of calf's sire, or the interaction between the two, on the IgG concentration in the plasma samples taken from the young calves (Table 3). All except seven calves (AA, n = 5; AF, n = 1; AJ, n = 1) had adequate concentrations of IgG. There was an interaction between the effect of cow genotype and breed of calf's sire on GGT activity: Simmental-sired calves had less (P <0.05) GGT activity than Angus-sired calves for AF cows, but there was no effect (P >0.05) of sire breed on GGT activity for calves born to AA, AK or AJ cows. Seven calves did not have adequate GGT activity and all of these calves had AA dams. There was no effect (P >0.05) of either cow genotype or breed of calf's sire on the serum total protein concentration of the calves, however, female calves had a greater (P <0.05) concentration than the male calves. Four calves (AA, n = 3; AJ, n = 1) had inadequate serum protein concentrations.

There was no difference (P >0.05) in weaning rate between any of the cow genotypes (Table 4). A total of nine calves did not survive from birth until weaning (AA, n = 3; AF, n = 3; AJ, n = 3). Simmental-sired calves had greater (P <0.05) ADG than Angus-sired calves and male calves had a greater (P <0.05) ADG than female calves. Calves born to either AF or AK cows had the greatest ADG, which was greater (P <0.05) than the ADG of the calves born to AJ cows, which was in turn greater (P <0.05) than that of calves born to AA cows. AA cows produced the lightest (P <0.05) calves at weaning, AF and AK cows produced the heaviest (P <0.05) calves at weaning and AJ cows produced calves that were intermediate. Simmental-sired calves were heavier (P <0.05) at weaning than Angus-sired calves. Male calves were heavier (P <0.05) than female calves at weaning.

AJ cows were more efficient (P <0.05), in terms of kg of calf per kg of cow live weight at calf weaning, than AF cows, which were in turn more efficient (P <0.05) than AA cows. AK cows were also more efficient than AA cows, which had the least weaning efficiency. Dams of male calves were more efficient (P <0.05) than dams of female calves.

After all cows were joined with the Charolais bulls, two AJ cows and one AK cow were not pregnant.

Discussion

Weaning efficiency takes into consideration both cow live weight as a proxy for maintenance feed costs, and weight of calf weaned. Therefore, for a cow to have a greater efficiency it must either be lighter, and consume less feed, and/or it should produce a heavier calf. However, a change in the size of cow does not consistently change the efficiency as there may also be a comparable change in the weaning weight of the offspring (Nicoll et al. 1978), which was seen among the high-milk genotypes. The three high-milk genotypes (AF, AK, AJ) all produced heavier calves than the AA cows, in agreement with previous studies (Arthur et al. 1997; Morris et al. 1993; Nicoll et al. 1978), as milk yield is thought to have a major effect on pre-weaning calf growth (Arthur et al. 1997; Nicoll et al. 1978). The greater milk production of these three genotypes supported greater ADG of their calves and in turn heavier weaning weights. This was most obvious when AJ cows were compared to AA cows. AJ cows were smaller, but because they had greater milk production, they weaned calves that were heavier than those born to AA cows.

Therefore, AJ cows were more efficient than the large, low-milk-producing AA cows. Increased milk production requires increased dam feed intake, so live weight alone cannot be used as a true measure of feed intake required to wean a calf. The extra feed cost of the increased milk production must also be considered for input comparisons between genotypes of differing milk production.

In agreement with Arthur et al. (1997), the high-milk genotype cows that produced heavier calves, had lower body condition scores. This is probably due to the cows using up their fat reserves to produce enough milk for their calves. AA cows, in contrast, were fatter and usually heavier than the other genotypes which contributed to their low efficiency. There was little change in BCS of the high-milk genotypes throughout the experiment, however, AA cows put on condition from pre-calving to weaning. This could allow them to go into next calving in a better condition than the high-milk genotypes. As a consequence the difference in body condition between the high- and low-milk genotypes could become more marked over time, giving AA cows a productive advantage in the future. Therefore, the future production of the high-milk genotypes should be considered as they may not be able to continuously support the large milk production that results in the heavy calf weaning weights.

The effects of both maternal and individual heterosis on the calves must be considered. A variety of genotypes were used in this experiment, ranging from straightbred calves (Angus cross AA), first-crosses (Simmental cross AA), back-crosses (Angus cross AF, Angus cross AK, Angus cross AJ) to three-breed crosses (Simmental cross AF, Simmental cross AK, Simmental cross AJ). The amount of heterosis in each of the calf genotypes would have varied considerably and could have affected the results reported here. However, the availability of replacement beef-cross-dairy heifers from the dairy industry means that this heterosis is a sustainable component of this breeding system.

Conclusion

The influence of high-milk-producing genetics increased the cows' efficiency by increasing the weaning weight of calves compared to the AA cows, regardless of the size of the cow genotype. This is because the high-milk genotypes were able to support greater growth rates through their greater milk production even in cases where the cow was smaller than the low-milk-producing AA. The high-milk genotypes had a lower BCS and rib-fat depth and so the ability of these animals to continue to support the high-milk production and the greater calf growth rates by using their fat stores must be considered for future years, as beef cattle are often not provided with the best quality feed. Overall, cow size alone did not affect weaning efficiency. The potential milk production of the cows was very important because of the effect on calf weaning weight. Efficiency is important as bigger cows require more feed due to greater energy requirements for maintenance. Increased cow size must support heavier calves in order to maintain efficiency. High efficiency could be achieved by using high-milk-producing genotypes, regardless of the live weight of the dam, but light, high-milk dams were most efficient.

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