THE IMPACT OF SELECTING FOR MARBLING ON BEEF COW HERDS

for

Certified Angus Beef
Manhattan, Kansas

by

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Introduction Definitions and Heritability

Value-based marketing and the advent of industry alliances have increased the awareness and profitability of beef carcass quality. Pricing cattle on an individual animal basis rather than on the average of a group makes those traits related to the end product more valuable to the cattle feeder and breeder. Hopefully, demand for high quality beef will increase interest and support for source verification from the different segments of the beef industry. Identification of producers possessing high quality cattle will increase their bargaining power and profits. Net profits will rise only if a balance between product quality/value and cowherd production costs can be achieved. Major factors in cowherd profitability will continue to be greatly influenced by reproductive rates, calf growth, and cow maintenance costs. Even though the quality of beef has been a major concern of cattle producers for decades, the lack of real premiums has forced most selection pressures to be put on growth and reproduction traits. Through these selection efforts, producers have substantially reduced their cost of production. These advances in animal breeding can not be abandoned (Siegfried, 1998). But, the decrease in consumer demand for commodity beef (Purcell, 1998) has renewed the emphasis cattle breeders and feeders need to place on meat quality.

Beginning in 1928 with the publication of USDA standards for beef carcass quality, the United States cattle industry has had a system of grades to classify their products. Over the years, modifications and additions have been implemented to update and improve the applications of those standards. However, three carcass characteristics (marbling, lean texture and color, and physiological age) have controlled the quality grading standards. Most notably marbling and muscle characteristics have been the major factors in quality grade separation (USDA, 1979 and 1996).

Marbling is defined as the specks of intramuscular fat distributed in muscular tissue and is usually evaluated in the ribeye between the 12^{th} and 13^{th} rib (BIF, 1996). Prior to the advent of ultrasonography the only way to estimate the amount of marbling was to visually examine a cross-section of the ribeye surface. To establish breeding value estimates for the marbling trait, extensive progeny testing is required. Even though progeny testing is a slow, time consuming, tedious methodology, it has and will continue to be the main source of definitive EPD information. However, with the addition of ultrasound the collection of carcass trait data and hence genetic progress should be greatly enhanced (Houghton and Turlington, 1992; Brethour, 1994; Moser et al., 1998).

Studies have measured the differences in marbling both between and within breed populations. Numerous trials (Urick et al. 1991; DeRouen et al., 1992; Marshall, 1994; Gregory et al., 1995; Wheeler et al., 1996; O'Connor et al., 1997; Sprinkle et al., 1998; Cundiff et al., 1998) have reported differences among the major breeds of cattle. From these trials it is can be concluded that *Bos indicus* breeds do not have the genetic capability to marble like *Bos taurus* breeds. Among the *Bos taurus* breeds it appears that British breeds are superior to continental breeds in marbling ability (Cundiff et al., 1993). Furthermore, adequate differences in breeding values for marbling exist within breeds (Vieselmeyer et al., 1996; AAA, 1999) so that cattle producers can change the marbling potential of their cattle irrespective of breed.

Average heritabilities for marbling have been estimated in many genetic trials. Table 1 is a partial listing of those results. Heritability is defined as the proportion of phenotypic variation that is due to additive gene effects (Buchannan and Clutter, 1989). In laymen terms, heritability is the proportion of what you measure that is caused by genetics and not by environment. Reproduction traits are low, growth traits are usually moderate and carcass and mature traits are generally high in heritability. This means that genetic greatly influences traits like marbling much more than pregnancy rates. It also means that heterosis will be more effective in improving reproductive and growth traits than carcass traits. There are no free rides in carcass genetics; either the genes are present for marbling or they are absent. No amount of feed will express more marbling than is genetically possible (Urick et al., 1991; May et al., 1992).

Marbling and Reproduction

One question often asked by cattle producers is: Does selection for marbling effect reproductive efficiency of the cowherd? No scientific studies can be found that directly address this question, but several studies do exist that provide guidance. Bergfeld and coworkers (1995) examined the age at puberty in heifers sired by Angus bulls considered high or low in marbling EPD. They found no difference in the age of puberty onset between the different sire groups. Gregory et al. (1993) and Cundiff et al. (1993) reported breed differences in puberty age, scrotal circumference, reproductive traits, maternal and marbling scores of cattle used it the MARC germplasm projects. These data indicate that breed or biotype has more influence on reproductive ability than marbling potential. The average genetic correlation between preweaning gain and marbling score has been reported to be .39 (Ritchie, 1999) and .21 (Splan et al., 1998). This is quite favorable if genetic selection for weaning weight and marbling are desired in the same direction. Because of the direct, positive relationship of weaning weight and dam's milk production (Knapp and Black, 1941; Neville et al, 1960; Wyatt et al., 1977; Boggs et al., 1980; Marston et al., 1992) one would speculate that increased milk production would also be positively associated with greater of marbling potential. Kuhlers and Jungst (1992) reported that breeding lines of swine selected for increased 70-day litter weight produced market hogs that had greater marbling scores. To achieve greater 70-day litter weights, sows were selected for increased milk production, increased litter size and increased pig survivability. This would indicate that selecting for increased milk production genetically drags an along increased ability to marble. The question then becomes: Is the inverse true? Generally speaking, I would suggest that it does. However, Fiss and Wilton (1993) uncovered no relationship between dam's milk yield and any feedlot or marketing trait measured in their progeny. Arnold et al. (1991) reported a positive genetic relationship between post weaning rate of gain and marbling. This would indicate that the environmental conditions during the finishing phase would be able to limit the expression of marbling but not enhance it past the animal's genetic potential.

Because milk production is highly related to preweaning weight gain, producers often wonder if overall milk yield or milk composition is important. There are documented differences in milk composition among beef and dairy breeds (Marston et al., 1992; Boweditswe et al., 1992). The Jersey breed is noted for high milk fat concentration and total production, and according to MARC data (Cundiff et al., 1988) it is one of the highest breeds for marbling. A correlation between the ability to produce greater amounts of butterfat and marbling may exist, but presently no data is available to can substantiate this interesting hypothesis. Table 2 shows the levels of milk, marbling and growth of sire breed groups in MARC studies (Cundiff et al., 1988). Beal et al. (1989) machine milked Angus and Angus x Holstein crossbred cows and found that the milk fat content varied by the genetic makeup of the cows and by the day of lactation. Totusek et al. (1973) reported butterfat content had no influence on calf growth rates or weaning weight. If milk composition can not be shown to influence growth rate during the suckling period, the question then becomes where would a relationship between butterfat and marbling take place? If not in calf performance then it would have to occur within a basic metabolic pathways which influence partitioning of energy within the body and among differing fat stores.

Marbling and Body Type

Conversations with producers of various breeds have noted a concern that pregnancy rates of virgin heifers and subsequent breedings are lower in heifers of higher marbling parentage. The present review of data does not substantiate this review. Since reproduction is a lowly heritable trait and marbling is a moderate to highly heritable trait, this review would suggest that the genes controlling reproduction and marbling would have to overlap and effect multiple traits for this to be true genetic relationship. However, evidence exists, and field observations note, that those progeny of higher marbling parents seem to also have a higher propensity to produce milk. If this is indeed the case, and if multiple trait selection is not practiced to select those individuals that excel in marbling yet are only moderate for milk, than the increased nutrient demand for milk production would definitely limit reproduction in environments with limited nutritional resources (Rawlings, 1998). Therefore, it is important for cattle producers to monitor multiple traits so that genetic selection does not impede reproductive performance.

Vizcarra and coworkers (1995) at Oklahoma State University indicated that heifers that reach puberty first in both age and weight have the ability to cycle and maintain fertility with less weight gain after severe nutritional challenges. This would suggest that if cattle were simultaneously selected for high marbling and for puberty age and(or) scrotal circumference than reproductive efficiency could be maintained even in less than ideal environments. Yelich et al. (1992) reported that puberty age in heifers is controlled by the rate of gain and body composition. He concluded that puberty is partially controlled by fat deposition. Gaughan et al. (1997) studied gilts and agreed with Yelich that age of puberty is influenced by the rate of fat and protein deposition. Therefore, cowherd managers must provide an environment conducive to proper heifer development and cow maintenance to maintain reproductive efficiency.

Because of the relationship between marbling and overall fat accumulation, there appears to be an antagonistic relationship between marbling and cutability across breeds and within some breeds (Marshall, 1994). The American Angus Association (1999) reported only a minimal correlation (-.04) between marbling and percent retail product. This should be comforting to Angus breeders as it allows them to more freely select for the both quality and quantity of red meat. Many cattlemen and cattle evaluators assume that the ability of cows to fatten and their "do ability" are positively correlated. Furthermore, the ability of cattle to accumulate back fat and to marble (AAA, 1999; genetic correlation between marbling and fat thickness = .02) are not correlated, implying that Angus breeders have the ability to match both marbling ability and do-ability to their particular management systems. Berg and Butterfield (1976) reported that Angus steers tend to deposit a fairly fixed proportion of internal and external fat at early stages of fattening and these proportions persist to high levels of fattening. This would allow reproduction and sustainability of a cowherd to be maintained while selecting for high quality beef production. However, when producers try to lower backfat and increase marbling simultaneously, slower progress will be made in both traits than if only one trait is emphasized. These two traits appear to be antagonistic in most studies (Urick et al., 1991; DeRouen et al., 1992; Gregory et al., 1995; USDA, 1996). After reviewing the American Angus Association Sire Summary (1999) and research using Angus bulls, it appears that EPDs can be used for genetic selection and trait movement that would normally be thought antagonistic. MacNeil et al. (1984) predicted that selection for reduced back fat (or increased percentage of retail product) would be associated with increased mature weight, increased age and weight at puberty, and reduced fertility of females. No studies can be found to confirm or contradict these predictions of increased mature weight and reduced female fertility. MacNeil did not examine the direct consequences of increased marbling selection.

Has the changes in body type altered the ability to marble over the last several decades? One breeder and cattle evaluator was asked if any physical differences were noted among the high marbling population. His reply: "The heifers seem to reach puberty about the same age as their counterparts, the cattle as a whole are flatter muscled, growth may be slightly compromised, and they reach mature weights [that are] slightly less than the rest of the population". This is appears to be supported by several research reports. Vieselmeyer et al. (1996) bred cows to high and low marbling Angus bulls and collected data on their offspring until slaughter. They found no differences in birthweight or dystocia, post-weaning weight gain or feed efficiency while in the feed yard. He did note that the calves in the low marbling group weighed more at weaning than their sire EPDs would have predicted, but the weight advantage was lost during the finishing phase. Hopper et al. (1993) noted no significant difference in puberty age of heifers that differed in marbling score potential. Bergfeld et al. (1993) reported no difference in the puberty age of heifers from the same sires used in the Vieselmeyer experiment and this conclusion was substantiated by Span et al. (1998). Numerous reports have indicated that higher marbling cattle have compromised rib-eye area (Gwartney et al., 1996; Hammack, 1997; Pariacote et al., 1998). Fiss and Wilton (1993) noted that calves expressing greater marbling scores tended to be the offspring of lighter weight cows.

An interesting study by May and coworkers (1995) examined the results of breeding crossbred cows to Angus bulls born in either the 1960's or 1980's. No EPD criteria was used in bull selection; their use was based only on semen availability. The results were as expected for many of growth traits when genetic trends were taken into account (AAA, 1999). Newer generation-sired calves were heavier and larger framed throughout life. Carcass data analysis noted no differences in fat (adjusted fat thickness, KPH, or marbling scores) or muscle measurements but there was a difference in USDA yield grade. Smaller ribeye areas per hundredweight of carcass appeared to cause the decline in cutability of the calves sired by 1980's bulls. They also noted differences in characteristics of the marbling fat cells. Detailed analysis found that the 1980's sire calves required more adipocytes to achieve that same amounts of marbling. Others (Jacobi and Miner, 1999) are seeking ways to manipulate the expression of marbling but this research is in its infancy. Cattle breeders must rely on genetic selection to make changes in marbling potential.

Unfortunately, breeding experiments have not been completed to address the relationship between marbling, milk production, and reproduction with a particular biotype or breed. Iowa State University is presently developing a herd of Angus to address this desperately needed information (D. Wilson, personal communication). Until their data is analyzed, we can only speculate as to the results.

Correlation between Marbling EPD and Other Performance EPDs

The authors took the liberty to determine the correlation between marbling EPD and other performance trait EPDs on the high accuracy marbling bulls listed in the Spring 1999

Angus Sire Summary. One hundred forty-five bulls were listed in the summary with accuracies for marbling EPD greater than or equal to .80. First, seventy-five sires representing the highest (n = 25), lowest (n = 25), and moderate (n = 25) marbling EPDs bulls were compared. The results are listed in Tables 3 - 6. These tables show the similarity between the three marbling groups of bulls. After reviewing the means, ranges, minimums, and maximums, it became quickly apparent that regardless of the genetic direction a cattle breeder wants to move his herd in marbling, there are bulls available to positively effect other important traits. In the moderate group there appeared to be a significant negative relationship between marbling and milk, which is surprising and opposite to the results from the combined data sets. Trends that appeared across the combined marbling groups show a tendency for birth weights to drift lighter and milk production higher as marbling increases.

The database was expanded to include all 145 bulls listed with marbling EPD accuracies of greater than or equal to .80 (Tables 8 and 9). From the earlier analysis, my expectations were to reaffirm the relationship between daughter's milk production potential and offspring birth weights. Most of the outliers on the enlarged data set were to be nested within the first analysis. Significant correlation coefficients between marbling and birth weight EPDs were erased in the second analysis. However, correlations between direct weaning weight and milk were observed. Direct weaning weight EPD tended to decrease and milk EPD increase as marbling EPD increased. In principle, this would translate to fleshier weaned calves that would not necessarily weigh more than contemporaries.

Conclusions and Closing Thoughts

Marbling is an economically important trait in today's beef cattle industry. For several decades there has been a movement toward value-based marketing. Within the next five years the movement will be escalating at an exponential rate. This will allow cattle producers to financially benefit from incorporating superior genetics into their programs. For producers to maximize returns from tomorrow's marketing systems they will have to meet consumer demands in a efficient manner. Great genetic strides have been made in the improvement of efficient growth; now is the time for producers to maintain growth advantages and increase carcass quality.

Most pricing grids reward cattle feeders with premiums for high quality carcasses. These premiums will have the potential to add $20 to $70 per head to gross income. It is common for 500 or more pounds of growth to be added in the finishing phase. With these facts in mind, simple arithmetic indicates that performance can not be sacrificed to reap carcass premiums. Shortfalls as small as four cents per pound of gain will easily remove added carcass profits.

Marbling is a major contributor to determining carcass quality. Like other production traits, marbling is controlled by genetics and environment. Research indicates that the heritability of marbling is moderate to high. Producers need to realize that genetics is more influential on the expression of marbling than on traits like weaning weight or calving percentage. Marbling has to be bred into the offspring, it can not be fabricated from a special environment. Today, we do not have an implant, injection or feed additive that enhances marbling score. Instead, quite to the contrary, most growth stimulants utilized in today's modern finishing programs hinder marbling expression (Duckett et al., 1997).

Producers are questioning the wisdom of selecting strictly for marbling. This is well advised, as single trait selection has been shown to be detrimental to other important production traits. For example, if yearling weight is the only selection criteria, birth weights will increase and eventually dystocia would hinder overall production of the cow herd. Because of known relationships between marbling and other carcass traits, selecting cattle only to increase marbling will result in finished cattle that will be lighter muscled, fatter, and have a lower percentage of retail product.

Age of puberty does not seem to be affected by marbling potential. Several experiments have shown no difference in pubertal age; however, differences in fertility were not reported. Fortunately, heifers and cows that exhibit estrus are usually fertile. Along with changes in carcass characteristics one would expect high marbling cattle to be higher in milk production which would promote heavier weaning weights. Direct growth for weaning weight would not be expected to change; therefore, weaned calves may be expected to be carrying additional condition or flesh. Cows with greater genetic potential to milk have metabolic rates that demand more energy for maintenance than lower milking contemporaries (Andersen, 1978; Lemenager et al., 1980).

All to often, cow-calf producers do not adequately consider the ramifications of increasing production parameters such as milk production and weaning weight. Greater demands on body energy reserves may cause reductions in reproductive performance. If management does not properly match genotype to environment the cowherd will begin to experience lower reproductive rates caused by decreased body condition scores. Actually, we know little about the peculiarities of dams that possess high marbling genes. Research projects are presently being designed to address these pressing questions (D. Wilson, personal communication).

The solution is to use multi-trait selection based on EPDs. Considering multiple traits simultaneously would minimize many of the unfortunate scenarios being reported from field observations. Breeders need to rely heavily on the American Angus Association Sire Summary publication and visual observations of type and kind. Accurate data collection is the cornerstone to the system. Assembly of the data into organized information and turning that information into concrete knowledge is the most efficient system to improve cattle breeding and meet the demands of our consumers.

Tables

Table 1. Heritability estimates of marbling in beef cattle.

Study	Year	Heritability estimate
Benyshek	1981	.56
Arnold	1991	.35
Wilson & Rouse	1987	.31 (light steers)
Wilson & Rouse	1987	.26 (heavy steers)
Gregory et al.	1995	.46 (all breeds)
Gregory et al.	1995	.45 (purebreds)
Gregory et al.	1995	.55 (composites)
Gregory et al.	1994	.52
Woodard	1992	.23 (Simmental)
Pariacote et al.	1998	.88 (Shorthorn)
Veseth et al.	1993	.18 (Herefords)
Wulf et al.	1996	.51
O'Conner et al.	1997	.37
Amer. Angus Assoc.	1999	.38
Average		*.43*

Table 2. Breed crosses grouped into seven biological types on the basis of four major criteria and marbling score [ab].

Sire Breed Group	Growth Rate	Lean to Fat	Puberty Age	Milk Production	Marbling Score
Jersey	X	X	X	XXXXX	13.2
Hereford-Angus	XX	XX	XXX	XX	11.3
Red Poll	XX	XX	XX	XXX	11.5
Devon	XX	XX	XXX	XX	
South Devon	XXX	XXX	XX	XXX	11.3
Tarentaise	XXX	XXX	XX	XXX	10.2
Pinzgauer	XXX	XXX	XX	XXX	10.8
Brangus	XXX	XX	XXXX	XX	
Santa Gertrudis	XXX	XX	XXXX	XX	
Sahiwal	XX	XXX	XXXXX	XXX	9.7
Brahman	XXXX	XXX	XXXXX	XXX	9.3
Brown Swiss	XXXX	XXXX	XX	XXXX	10.4
Gelbvieh	XXXX	XXXX	XX	XXXX	9.6
Holstein	XXXX	XXXX	XX	XXXXX	
Simmental	XXXXX	XXXX	XXX	XXXX	9.9
Maine-Anjou	XXXXX	XXXX	XXX	XXX	10.1
Limousin	XXX	XXXXX	XXXX	X	9.0
Charolais	XXXXX	XXXXX	XXXX	X	10.3
Chianina	XXXXX	XXXXX	XXXX	X	8.3

[a]Increasing number of X's indicate relatively higher levels of performance and older age at puberty.

[b]Marbling: 8 = slight, 11 = small, 14 = modest.

Adapted from Cundiff et al., 1988.

Table 3. Statistics of the 25 high marbling (greater or equal to .34 marbling EPD) Angus bulls used in correlation analysis.

Trait	Mean	SD	Minimum	Maximum
Year of birth	1988.8	4.2	1975	1995
EPDs				
Birth weight	1.9	1.5	-1.9	4.5
Weaning weight	29.0	9.1	12.0	48.0
Milk	18.4	6.6	7.0	33.0
Yearling weight	60.2	15.6	27.0	94.0
Combined maternal	33.0	8.7	13.0	52.0
Marbling	.48	.12	.34	.76
Mature weight	15.5	29.4	-13.0	109.0
Mature height	.8	.5	.2	2.4
Scrotal Circumference	.18	.67	-1.20	1.53

Table 4. Statistics of the 25 moderate marbling (.06 to .12 marbling EPD) Angus bulls used in correlation analysis.

Trait	Mean	SD	Minimum	Maximum
Year of birth	1988.2	3.5	1980	1994
EPDs				
Birth weight	1.8	2.5	-1.8	6.8
Weaning weight	32.5	7.7	16.0	50.0
Milk	19.2	7.9	2.0	35.0
Yearling weight	63.3	10.1	42.0	83.0
Combined maternal	35.5	7.9	20.0	48.0
Marbling	.09	.02	.06	.12
Mature weight	8.2	24.1	-41.0	45.0
Mature height	.8	.5	.1	1.8
Scrotal Circumference	-.01	.59	-.99	1.40

Table 5. Statistics of the 25 low marbling (-.11 to -.57 marbling EPD) Angus bulls used in correlation analysis.

Trait	Mean	SD	Minimum	Maximum
Year of birth	1986.1	6.2	1973	1994
EPDs				
Birth weight	3.0	2.3	-2.5	5.9
Weaning weight	30.9	6.8	14.0	42.0
Milk	14.7	8.9	-7.0	34.0
Yearling weight	60.2	15.0	28.0	92.0
Combined maternal	30.2	9.0	14.0	51.5
Marbling	-.24	.12	-.57	-.11
Mature weight	6.1	27.6	-60.0	61.0
Mature height	.7	.5	-.2	1.8
Scrotal Circumference	-.02	.56	-1.06	1.47

Table 6. Statistics of the combined 25 high, 25 moderate, and 25 low marbling EPD Angus bulls used in correlation analysis.

Trait	Mean	SD	Minimum	Maximum
Year of birth	1987.7	4.8	1973	1995
EPDs				
Birth weight	3.2	2.2	-2.5	6.8
Weaning weight	30.8	8.0	12.0	50.0
Milk	17.5	8.0	-7.0	35.0
Yearling weight	61.2	13.7	27.0	94.0
Combined maternal	32.9	8.7	13.0	52.0
Marbling	.11	.31	-.57	.76
Mature weight	10.0	26.9	-60.0	109.0
Mature height	.8	.5	-.2	2.4
Scrotal Circumference	.04	.61	-1.20	1.53

Table 7. Correlation coefficients[a] between marbling EPD and other traits of 75 Angus bulls that comprise the highest, middle and lowest marbling EPD (accuracy of .80 or greater).

	Grouping by marbling EPD			
	High	Moderate	Low	Combined
	Marbling EPD			
Trait	≥ .34	.06 to .12	≤ -.11	
No. of bulls	25	25	25	75
Year of birth	.067 (.74)	-.216 (.30)	-.039 (.85)	.21 (.07)
EPD				
Birth weight	-.255 (.74)	.088 (.68)	-.121 (.57)	-.21 (.07)
Weaning weight	-.129 (.22)	.110 (.60)	-.262 (.21)	-.14 (.22)
Milk	-.002 (.99)	-.348 (.08)	.252 (.22)	.20 (.08)
Yearling weight	-.257 (.22)	-.106 (.61)	-.063 (.76)	-.05 (.64)
Mature weight	-.073 (.75)	.035 (.88)	-.138 (.56)	.11 (.38)
Mature height	-.193 (.39)	.185 (.40)	.106 (.66)	.09 (.47)
Scrotal circ.	-.127 (.54)	.143 (.15)	-.198 (.34)	.09 (.45)

[a]Tabular values are Pearson correlation coefficients followed by P values within parenthesis.

Table 8. Statistics of high accuracy (≥ .80) marbling EPD bulls (n = 145) listed in the Spring 1999 Angus Sire Summary.

Trait	Mean	SD	Minimum	Maximum
Year of birth	87.6	4.9	70	95
EPDs				
Birth weight	2.6	2.4	-2.7	8.7
Weaning weight	32.0	9.0	10.0	57.0
Milk	16.6	7.9	-7.0	38.0
Yearling weight	62.2	15.3	22.0	106.0
Combined maternal	32.9	8.7	13.0	52.0
Marbling	.11	.25	-.57	.76
Mature weight	11.4	27.6	-61.0	109.0
Mature height	.8	.6	-.4	2.4
Scrotal Circumference	.08	.58	-1.28	1.53

Table 9. Correlation coefficients between marbling and other production traits of high accuracy (≥ .80) marbling EPD bulls listed in the Spring 1999 Angus Sire Summary.

Trait	Pearson Correlation Coefficient (P value)
Year of birth	.074 (.37)
Birth weight	-.101 (.23)
Weaning weight	-.138 (.10)
Milk	.124 (.13)
Yearling weight	-.093 (.27)
Mature weight	.091 (.31)
Mature height	.061 (.50)
Scrotal circumference	.043 (.61)