1993

Genetic Parameters for Carcass Traits in Beef Cattle

D. M. Marshall
South Dakota State University

GENETIC PARAMETERS FOR CARCASS TRAITS IN BEEF CATTLE

D. M. Marshall[1]
Department of Animal and Range Sciences

CATTLE 93-8

Summary

The recent scientific literature was reviewed to summarize genetic parameters for carcass traits in beef cattle. Heritability estimates were generally moderate to large, in agreement with previous literature estimates. This suggests good potential for making change through genetic selection for a given individual carcass characteristic. However, genetic improvement through multiple-trait selection would be slowed by several important genetic antagonisms between traits, suggesting the use of terminal breeding systems with complementary sire and dam genetic types. Individual and maternal heterosis estimates from age-constant analyses were numerically positive and quite large for fat thickness and tended to be numerically positive and small to modest in magnitude for most other carcass traits. Hence, potential contributions to improved carcass composition from crossbreeding would primarily result from genetic complementarity rather than heterosis. As the U.S. beef industry presumedly moves toward a more value-based marketing system, genetic concerns include 1) an apparent antagonistic genetic relationship between marbling and cutability in some populations, 2) the effect of increased leanness on maternal productivity, and 3) the extent to which terminal breeding systems can be used.

Key Words: Cattle, Body Composition, Breed Differences, Carcass, Genetic Parameters

Introduction

Beef cattle genetic improvement programs have traditionally focused primarily on growth traits. However, as consumers become more concerned with diet-health issues and as the beef industry focuses more on value-based marketing, then emphasis on body composition traits is expected to become increasingly important in the design of breeding programs. In order to compete with other sources of food protein, the beef industry must produce specified meat products in a predictable and cost-efficient manner. Beef breeders are faced with the challenge of utilizing diverse resources to produce cattle that are profitable to all segments of the industry and meat products that are in demand by consumers. To accomplish these goals, breeders need information on estimates of genetic parameters for a wide spectrum of traits in order to develop effective breeding schemes. The objective of this paper is to present a review of the scientific literature on genetic parameters for beef cattle carcass traits and relationships of carcass traits with growth traits.

Discussion

Heritability measures the extent to which observed (phenotypic) differences among individuals may be passed on from one generation to the next for a particular trait. Heritability varies from trait to trait and from population to population. Heritability estimates from the recent scientific literature were generally moderate to large for carcass traits in age-constant analyses (Table 1). Arnold et al. (1991) reported weight-constant heritabilities of .24, .46,

[1]Associate Professor.

Table 1. Heritability estimates for carcass traits (age-constant basis)

Trait	Source[a] 1	2	3	4	5	6	7	8	9	10	Avg
Carcass wt	.68	.43	.48	.44	.31		.33				.45
Longissimus muscle area	.28	.56	.40		.28		.01		.60		.36
Fat depth	.68	.41	.52		.24	.52					.47
Marbling score	.34	.40	.47		.33				.45	.23	.37
Est. cutability		.63[b]	.49		.23					.18	.38
Retail product wt	.38	.58		.45				.47			.47
Est. retail cuts per day of age										.30	.30
Fat trim wt	.94	.47		.50							.64
Fat trim percentage		.57									.57
Bone wt	.94	.57									.76
Bone percentage		.53									.53
Warner-Bratzler shear force		.31						.71	.09		.37
Sensory panel tenderness									.10		.10
Calpastatin activity								.70			.70

[a]Source	No. offspring	No. sires	Population
1. Koch et al. (1978)	377	64	Hereford
2. Koch et al. (1982)	2,453	370	Crossbreds
3. Benyshek et al. (1981)	8,474	1,524	Hereford field data
4. MacNeil et al. (1984)	5/sire	187	Crossbreds
5. Lamb et al. (1990)	824	95	Hereford
6. MacNeil et al. (1991)	4.25/sire	124	Several breeds
7. Reynolds et al. (1991)	139	30	Hereford
8. Shackelford et al. (1992)	555		Crossbreds
9. Van Vleck et al. (1992)	682	111	Crossbreds
10. Woodward et al. (1992)	8,265	420	Simmental field data

[b]Actual percentage retail cuts.

.49, and .35 for carcass weight, longissimus muscle area, fat depth, and marbling, respectively, in a study of 2,411 Hereford steers from 137 sires. These values support the common presumption that selection on individual carcass traits should generally be relatively effective in many beef cattle populations.

Both phenotypic and genetic correlations are presented in this paper. A phenotypic correlation expresses the observable or measurable association between two traits which can be influenced by both genetic and environmental factors, whereas a genetic correlation expresses the association between traits due only to genetic factors. From a genetic improvement standpoint, genetic correlations are of primary interest. A genetic correlation between two traits exists when genetic factors affecting one trait are not independent of the genetic factors affecting the second trait, the practical consequence being that selection for change in one trait will simultaneously cause change in the second trait whether intended or not. A correlation near zero indicates that the two traits are more or less independent of one another, whereas a correlation near -1 or 1 indicates a relatively strong association between the two traits. A favorable genetic correlation means that selection for improvement in one trait will also improve the correlated trait. An unfavorable or antagonistic genetic correlation means that selection for improvement in one trait might impede improvement in the correlated trait. An antagonistic genetic correlation does not necessarily mean improvement can't be made in both traits simultaneously, although improvement in one or both traits may be slowed as compared to selection for only one of the two traits.

Some readers might question why genetic parameters sometimes vary quite radically across different studies. Keep in mind that the values presented are only estimates of the true population parameters. The possible error associated with the estimation procedure can be quite large. Secondly, genetic parameters can vary across different populations and over time within a population. Another point which should be made is that some estimation procedures can result in estimated values that are outside the theoretical range of possible values. For example, correlations can range only from -1 to +1. However, estimates of correlations may sometimes lie outside that range.

Genetic and phenotypic correlations of carcass traits with preweaning and postweaning growth rate from age-constant analyses are presented in Table 2. Positive genetic and phenotypic correlations were found for preweaning and postweaning growth rate with carcass weight, longissimus muscle area, and retail product weight. Genetic correlations with carcass fat thickness were positive for preweaning growth (averaged .37) and quite variable for postweaning growth (ranged from -.20 to .62, averaging .13). Genetic correlations with preweaning and postweaning growth, respectively, averaged .36 and .52 for fat trim weight and .08 and .12 for fat trim as a percentage of carcass weight. Relatively weak negative correlations were observed between growth rate and cutability or retail product percentage. These values suggest selection for reduced carcass fatness could be somewhat antagonistic to increased growth rate, particularly for growth prior to weaning. From weight-constant analyses, Arnold et al. (1991) reported that fat thickness was negatively genetically associated with weaning weight (r_g = -.28) but positively associated with postweaning gain (r_g = .17).

The average genetic correlation between preweaning growth and marbling score was .39 (Table 2), indicating a moderate, favorable relationship between selection for increased weaning weight and increased marbling. The average genetic correlation between postweaning gain and marbling was .05, indicating near independence between the two traits, although the variation in estimates across studies (r_g ranged from -.62 to .48) indicates that the relationship may be quite different across different populations. Arnold et al. (1991) reported that marbling was uncorrelated with weaning weight (r_g = -.01) and positively correlated with postweaning gain (r_g = .54) on a weight-constant basis.

Age-constant genetic correlations among carcass traits (Table 3) suggest that selection for reduced carcass fat thickness would be compatible with selection for larger longissimus muscle area and improved cutability. A selection antagonism is indicated between decreased fatness and increased marbling. Arnold et al. (1991) also reported that reduced fat thickness was associated with larger longissimus muscle area (r_g = -.37) and reduced marbling (r_g = .19) in weight-constant analyses.

It is interesting to compare genetic correlation estimates involving marbling to those involving Warner-Bratzler shear force. Marbling is currently the primary factor used by the beef industry to evaluate carcass quality of young cattle. Marbling may be related to flavor, juiciness, and tenderness, although its relative

Table 2. Genetic and phenotypic correlations of carcass traits with growth traits[a]

	Phenotypic correlations		Genetic correlations	
	Weaning wt or preweaning gain	Postweaning gain	Weaning wt or preweaning gain	Postweaning gain
Carcass wt	.59 (1)	.74 (1)	.48 (1)	.78 (1)
	.61 (2)	.72 (2)	.73 (2)	.89 (2)
		.64 (5)	.94 (7)	.93 (5)
Longissimus muscle area	.23 (1)	.27 (1)	.16 (1)	-.07 (1)
	.25 (2)	.32 (2)	.49 (2)	.34 (2)
	.38 (5)	.34 (5)	.43 (3)	.48 (5)
Fat depth	.12 (1)	.32 (1)	.59 (1)	.62 (1)
	.31 (2)	.17 (2)	.04 (2)	.05 (2)
	.20 (5)	.29 (5)	.49 (5)	.05 (5)
		.24 (6)		-.20 (6)
Marbling score	-.05 (1)	.20 (1)	-.02 (1)	-.62 (1)
	.10 (2)	.07 (2)	.31 (2)	.15 (2)
	.15 (5)	.24 (5)	.71 (5)	.48 (3)
	.02 (10)		.16 (10)	
Cutability or retail product, %	-.29 (2)	-.15 (2)	-.03 (2)	-.13 (2)
	-.10 (10)		-.20 (10)	
Retail product wt	.59 (1)	.62 (1)	.37 (1)	.73 (1)
	.47 (2)	.66 (2)	.62 (2)	.73 (2)
		.74 (8)		.92 (8)
Fat trim wt	.35 (1)	.62 (1)	.40 (1)	.64 (1)
	.46 (2)	.37 (2)	.32 (2)	.40 (2)
Fat trim percentage	.31 (2)	.15 (2)	.08 (2)	.12 (2)
Warner-Bratzler shear force	.00 (2)	.02 (2)	-.05 (2)	.06 (2)
		-.12 (8)		-.44 (8)
Calpastatin activity		-.18 (8)		-.48 (8)

[a]Number in parenthesis is for the source of the estimate (see Table 1).

Table 3. Genetic (below diagonal) and phenotypic (above diagonal) correlations among carcass traits[a]

	Carcass wt	LMA	Fat depth	Marbling score	Est. cutability or retail product, %	Retail product wt	Fat trim wt	Fat trim %	Warner-Bratzler shear force	Sensory panel tenderness	Calpastatin activity
Carcass wt		.37 (1) .43 (2) .58 (5) .58 (11)	.42 (1) .36 (2) .38 (5)	.18 (1) .13 (2) .28 (5) .28 (11)	-.31 (1)	.84 (1) .84 (2)	.82 (1) .62 (2)	.34 (1)	.00 (2)		
Longissimus muscle area (LMA)	.02 (1) .44 (2) .65 (5) .80 (11)		-.08 (1) -.15 (2) .04 (5)	-.03 (1) .03 (2) .19 (5) .00 (9) .16 (11)	.27 (2)	.55 (1) .60 (2)	.07 (1) -.03 (2)	-.20 (2)	-.02 (2) -.05 (9)	.00 (9)	
Fat depth	.95 (1) .08 (2) .14 (5)	.03 (1) -.44 (2) -.04 (5)		.25 (1) .24 (2) .38 (5)	-.74 (2)	.07 (1) -.05 (2)	.65 (1) .77 (2)	.77 (2)	-.01 (2)		
Marbling score	-.33 (1) .25 (2) .64 (5) .38 (11)	-1.34 (1) -.14 (2) .57 (5) -.40 (9) .51 (11)	.73 (1) .16 (2) .73 (5)		-.37 (2) -.21 (5) -.15 (10)	-.04 (1) -.07 (2)	.35 (1) .36 (2)	.38 (2)	-.12 (1) -.18 (9)	.19 (9)	
Cutability or retail product %	-.11 (1)	.53 (2)	-.74 (2)	-.37 (2) -.36 (5) -.12 (10)		.23 (2)	-.91 (2)	-.98 (2)	.03 (2)		
Retial product wt	.80 (1) .81 (2)	-.02 (1) .72 (2)	.65 (1) -.34 (2)	-1.10 (1) -.02 (2)	.46 (2)		.38 (1) .13 (2)	-.19 (2)	-.07 (2) -.11 (8)		-.15
Fat trim wt	.90 (1) .45 (2)	.10 (1) -.28 (2)	.95 (1) .74 (2)	.33 (1) .42 (2)	-.91 (2)	.46 (1) -.12 (2)		.94 (2)	-.04 (2)		
Fat trim %	.13 (2)	-.48 (2)	.78 (2)	.34 (2)	-.98 (2)	-.44 (2)	.94 (2)		-.04 (2)		
Warner-Bratzler shear force	.00 (2)	-.28 (2) -.14 (9)	-.01 (2)	-.25 (1) -.53 (9)	-.16 (2)	.02 (2) -.08 (8)	.14 (2)	.16 (2)		-.70 (9)	.30 (8)
Tenderness		-.04 (9)		.74 (9)					-.96 (9)		
Calpastatin activity						-.20 (8)			.58 (8)		

[a]Number in parentheses is for the source of the estimate (see Table 1).

importance continues to be a topic of much debate. Shear force has been used primarily in research studies as a mechanical measurement of carcass tenderness. Unfortunately, genetic correlations (Table 3) indicate that selection for increased marbling would be expected to be antagonistic to selection for increased muscling, reduced carcass fatness, and increased retail product weight. On the other hand, genetic correlations of shear force with other carcass traits are either favorable or close to zero, suggesting that selection for improved shear force would be compatible with selection for improvement in most other carcass traits.

Another concern regarding possible antagonisms between traits are the effects of selection for leanness and muscling on cow maternal performance (e.g., fertility, mothering ability, etc.). There is little experimental evidence on genetic relationships between carcass traits of calves and maternal performance of their female relatives. Studies have indicated that a cow's own body condition can affect her rebreeding ability.

Heterosis estimates, expressed as percentages of straightbred means, were averaged across specific crosses within a study and then averaged across studies for a particular trait. Therefore, the values presented represent mean heterosis levels across many different breed crosses. The estimates included in Table 4 were from studies in which days fed or calf age was as a slaughter endpoint or statistical covariate. Individual heterosis estimates for carcass weight were consistently positive, as might be expected for a trait related to growth rate. Individual heterosis estimates for fat thickness were numerically positive and quite large (averaged 10.1%), indicating that crossbred cattle would tend to have fatter carcasses than their straightbred counterparts at a similar age or time on feed. Estimates of individual heterosis tended to be numerically positive and small to modest in magnitude for most other carcass traits. Maternal heterosis effects appear to be of minor importance for most carcass traits, although estimates for fatness were generally positive and quite large in some studies.

In general, it would appear that carcass composition tends not to be appreciably improved from heterosis. However, crossbreeding could potentially provide some benefit in carcass value through complementary blending of breeds. More importantly, so-called terminal-cross matings allow the use of dams that excel in maternal traits and sires that excel in growth and carcass traits, thus avoiding some of the problems associated with genetic antagonisms between traits which may occur in some straightbred breeding systems. The primary drawback to terminal breeding systems is that replacement females must be produced outside the terminal system, which may present a problem in some management situations such as relatively small herds.

In summary, as the U.S. beef industry presumably moves toward a more value-based marketing system, genetic concerns include 1) an apparent antagonistic genetic relationship between marbling and cutability (in some populations, at least), 2) the effect of selection for increased calf carcass leanness on maternal performance of females relatives, and 3) the extent to which terminal breeding systems can be used.

Table 4. Individual and maternal heterosis estimates (% of straightbred mean) for carcass traits averaged across breed crosses and studies

Trait	No. studies[a]	h_i, %	h_m, %
Carcass wt	12 (4)	6.5	3.6
Quality grade	6 (2)	1.6	.6
Marbling	7 (2)	3.8	-1.1
Fat depth	11 (4)	10.1	8.9
Kidney fat	6 (1)	4.9	7.6
Longissimus muscle area	9 (3)	4.1	3.3
Estimated retial product wt	2 (1)	6.6	2.2
Estimated cutability or retail product %	7 (1)	-.6	-2.5
Yield grade	1	5.4	
Estimated fat trim wt	1	3.8	
Fat trim %	1 (1)	6.3	12.7
Shear force	2 (1)	-6.7	.0
Dressing percentage	3	-.2	

[a]First number is the number of studies on which the value given for individual heterosis (h_i) is based. Number in parentheses is for maternal heterosis (h_m). References: Gregory et al. (1978); Drewry et al. (1979); Peacock et al. (1979, 1982); Bailey et al. (1982); Bertrand et al. (1983); Koch et al. (1983, 1985); Neville et al. (1984); Comerford et al. (1988); Arthur et al. (189); DeRouen et al. (1992).