OPTIMIZING COW SIZE AND EFFICIENCY TO MAXIMIZE PROFITABILITY

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Introduction

Every year around spring producers are faced with the decision of using bulls from various breeds available to them. If they are to listen to the latest trends, they may be looking for a moderate-size breed bull. If they think their cattle are too small, they may look for a large-size breed bull. However, profitability is seldom considered.

Over the years, a number of studies have evaluated the concept of size and profitability. Thanks to the efforts of researchers conducting these studies, it should be easier to determine an answer that may best fit a given farm or ranch environmental and economic conditions. In it simplest form, it can be generalized that size is usually related to production, but more resources are needed to maintain larger sizes. In its most complex form, larger size may mean more production on the hooves of a weaned calf, but less production/unit area. Or, more resources available (such as crop byproducts) can mean more pounds of TDN, or more pounds of feed, but feed may be sufficiently inexpensive to permit greater production at a lower price. Added to these confounding factors is the need to produce calves that will be sought by feeders for their potential acceptability as beef for today's consumers.

The following is a review of research evaluating differences in size effects on profitability for conditions similar to Minnesota. This raises another question: what is a typical Minnesota beef cow-calf farm or ranch? To answer this question correctly, anything from a hilly treeless warm-season grass pasture in Western and Northwestern Minnesota, to lush cool-season grass pastures surrounded by either hardwood forests or cropland in North, Central and Southern Minnesota. All these situations and their accompanying economic scenarios make it difficult to determine from this exercise a single size trend to consider for Minnesota for the next several years, but some tools to determine this for individual situations will be provided.

Factors Affecting Maintenance Requirements

Cow-calf productivity and economic efficiency is dependent almost totally on the amount of energy a cow requires to maintain herself. This is due to the fact that commercial cow-calf enterprises are limited to yearly output of a single calf/cow. Some income may be achieved through cull cow and bull, and replacement heifer sales. However, $500 income for sale of a live 500-lb calf must pay for the cost of providing a cow-calf unit's nutritional needs (pasture costs, winter hay needs, supplemental protein, vitamins and minerals), veterinary and medicines, labor, equipment, interests, land rent, taxes and miscellaneous expenses associated with operating the cow-calf herd. Under the best conditions, yearly cow-calf production costs can be as low as $250, but they can reach $450. Therefore, to study differences in cow productivity and economic efficiency, it is important to concentrate on maintenance requirements before evaluating potential production level and costs.

Research to date indicates that energy requirements for maintenance (ME_m), expressed as Mcal Metabolizable Energy (ME)/Metabolic Body Size ($BW^{.75}$), are positively associated with level of production achievable by the animal. Table 1 illustrates this concept. Maintenance requirements of non-pregnant, non-lactating cows of breeds with the potential to produce fast gains or high milk yields are greater than those of breeds that typically have slow gains or low milk yield. For instance, lowest maintenance requirements reported are those for Brahman cows in Texas (Solis et al., 1988), while highest maintenance requirements reported are those for Braunvieh cows in Nebraska (Ferrell and Jenkins, 1988).

Table 1. Maintenance requirements and production traits of cows of various breeds

Sire breed or breed	ME_m, Kcal/$kg^{.75}$	BW, lb	205-d Milk yield, lb	Weaning wt, lb/d of age
Angus	118	1285	3131	1.71
Braunvieh	184	1263	3967	2.22
Charolais-x	129	1610	3153	2.30
Chianina-x	158	1359	N/A	2.96
Gelbvieh-x	174	1351	3733	2.17
Hereford	120	1302	2620	1.78
Jersey-x	145	1069	3313	2.45
Limousin	127	1276	2968	2.10
Red Poll-x	149	1126	3445	2.07
Simmental	134	1371	3529	1.98
Shorthorn	126	1089	4134	2.64
Angus	92	1109		
Brahman	94	1096		
Hereford	95	1078		
Holstein	116	1203		
Jersey	140	869		

Adapted from Ferrell and Jenkins, 1988 and 1992, and Solis et al., 1988.

On the one hand, Brahman cattle evolved in tropical climates and had to cope with a tremendous heat load, humidity and insects. Low maintenance requirements were needed to prevent excessive heat production in a high temperature environment. Use of energy for gain or milk yield became a secondary trait to evolution of the Brahman in its original environment. On the other hand, Braunvieh (European Brown Swiss) cattle were selected for milk and meat production in the Swiss Alps. Therefore, the environment and selection that this breed has been subject to contribute to their high maintenance requirements.

It is important to remember that these estimates of ME_m were derived from non-pregnant, non-lactating mature females. Thus, although not challenged by additional needs during pregnancy or gestation, ME_m estimates reflect differences in a breed?s potentials for growth or milk yield. Apparently, organ size and metabolic capacity required to produce large amounts of milk or meat increase overall energy requirements for maintenance (Thompson et al., 1983; Jenkins et al., 1986; Ferrell and Jenkins, 1988; DiCostanzo et al., 1990; Ortigues et al., 1993b).

Biologic and Economic Efficiency

Up to this point, only one side of the equation has been evaluated. Based on this evaluation, one would conclude that cows with large production potential may influence biologic and economic efficiency negatively, especially when feed cost is high. However, calf production (output) and production costs (input in dollars), specifically feed costs, have not been considered. Consideration of output will determine biologic efficiency, and costs, combined with output, will impact economic efficiency.

Factors that affect biologic efficiency are a cow's maintenance, gestation and lactation requirements, reproductive performance (calves weaned/cow exposed), calf maintenance and gain requirements, calf's weaning weight. Equations to determine biologic efficiency consider the cost (in energy units) to produce a unit body weight of weaned calf, or some modification thereof (i.e., mass instead of energy units). Therefore, cows having a high potential for growth or lactation may compensate for their high maintenance requirements by producing sufficient pounds of weaned calf.

Factors that affect economic efficiency are value multipliers of input costs or production levels. Equations to determine economic efficiency consider cost to produce a unit body weight weaned calf or net profit (income minus costs). Thus, cows having low biologic efficiency, due to high input (feed energy) relative to calf's weaning weight may have a high economic efficiency when input costs (feed) are low. On the other hand, cows producing few or light calves may compensate for this by having low feed needs (low feed cost) in a situation where calves are sold at a premium. This highlights the importance of considering the nutritional and economic environment under which cattle are raised.

As expected, it is difficult to evaluate economic efficiency from one production cycle. Thus, simulation models or long term comparisons are conducted and will be reviewed later.

A 12-yr study conducted in Oklahoma evaluating cows of differing milk yield potential under extensive native range conditions (Neumann and Lusby, 1986) demonstrates the effect of nutritional environment on economic efficiency. Cows were supplemented with protein and energy during winter months. Hay was fed only when forage was covered with snow. Cows calved from December to February and were weaned at 240 d of age. Breeds evaluated were Hereford (HER), Holstein (HOL) and their cross (HXH). Within each breed, cows were fed two levels of winter supplementation designed as moderate or high. The moderate supplementation level was designed to meet requirements for reproduction of HER, while the high supplementation level was designed to meet the requirement for reproduction of HXH. A third very high level was designed to meet the requirements for reproduction of HOL and was fed only to a group of these cows. Sires used during the first year were Angus, while Charolais sires were used in later years. Table 2 summarizes the observations from this study. In this study weight increased with lactation potential; thus, it is difficult to separate effects of body weight (growth potential) from milk yield potential. The moderate level of supplementation was sufficient to maintain a 95% rebreeding rate for HER cows. Although milk yield increased for HXH and HOL cows and weaning weight increased as a response of this trend, increased requirements for reproduction of HXH and HOL cows reduced the pounds of weaned calf/cow 21 and 54 lb, respectively, for cows supplemented moderately. Return/cow was highest for HER cows supplemented moderately and lowest for HOL cows supplemented moderately.

Hereford cows in the high supplementation group weaned slightly lighter calves; this, and the higher expenditure for supplementation, contributed to decreasing return/cow to 10% of that of HER cows supplemented moderately. These findings indicate that both over- and under-supplementation of cows may yield decreased returns. Returns for HOL cows on the very high level of supplementation approached those of HER cows supplemented moderately because rebreeding percentage was almost 100%. This demonstrates that large, heavy milking cows, supplemented to maintain reproductive performance, may be able to compensate for their high maintenance requirements.

A recent study conducted in Nebraska (Table 3; Montaño-Bermudez and Nielsen, 1990) corroborates data from the Oklahoma study. Cows of relatively similar growth potentials but having different milk production potentials were evaluated. Feeding and management conditions were similar to those in the Oklahoma study, except that winter supplementation included grass hay during December and January, and alfalfa hay during February through March. Efficiency, calculated as weight of calf weaned/Mcal ME, favored low producing (2827 lb milk/205 d) cows. Cows having low milk yield potential had the lowest weaning weight/cow exposed, but also required the least amount of energy. Utilizing a calf price of $95/cwt and an approximate cost of $.0132/Mcal ME, economic efficiencies (return/feed dollar) would be $4.47, $4.31 and $4.38 for cows having low, medium and high milk yield potential, respectively. In this experiment, calves from high milk yielding cows would need to weigh 10% more at weaning to compensate for their dams' higher lactation and maintenance requirements and achieve economic efficiency similar to that of low producing cows.

Researchers at the Meat Animal Research Center in Nebraska conducted a 3-yr study evaluating weaning weight/Mcal consumed for each of nine breeds representing various growth and milk potentials (Jenkins and Ferrell, 1993). Their data indicated that under their conditions (similar to those of the previous study), heavier milking breeds may have increased biologic efficiency when their calves grow efficiently. Braunvieh cows consumed the highest amount of energy, but consistently weaned the heaviest calves/cow exposed (1243 lb in 3 yr). Also, low milk yield, high growth potential breeds may achieve greater efficiency if their energy needs are sufficiently low and their production potential sufficiently high. For instance, Limousin cows weaned calves 44 lb lighter than Braunvieh cows, but utilized 838 less Mcal than Braunvieh cows over 3 yr.

Table 2. Performance and economic efficiency of Hereford, Hereford x Holstein and Holstein cows through four calf crops

Item	Hereford		Hereford x Holstein		Holstein		
	Moderate	High	Moderate	High	Moderate	High	Very high
Mature weight, lb	1,010	1,030	1,045	1,070	1,230	1,180	1,215
Daily supplement postcalving, lb	2.9	5.6	3.0	5.8	3.4	6.0	8.3
Daily milk yield, lb	13	13	19	21	27	28	28
240-d weaning weight, lb	575	565	618	631	693	700	691
Forage intake, %[a]	100	102	115	112	141	140	134
Conception rate, %[b]	95	95	85	92	71	82	98
Annual calf weaned per cow, lb	546	537	525	580	492	574	677
Return per cow[c]	$79	$8	$5	-$25	-$97	-$94	$60
Cows per 1000 acres[d]	100	98	87	89	71	71	75
Return per 1000 acres	$7,900	$816	$417	-$2,223	-$6,864	-$6,680	$4,542

[a] Expressed as a percentage of Moderate Herefords as determined in drylot trials.
[b] Average of 2-, 3-, and 4-year old cows.
[c] Based on calf values of $70, $65, and $60/cwt for calves of Herefords, Hereford-x Holsteins, and Holsteins.
[d] Based on forage intake as determined in drylot and a carrying capacity of 7 acres per cow for Moderate Herefords.

Adapted from Neumann and Lusby, 1986.

Table 3. Economic and biologic efficiency of cows of various milk yield potentials

Item	Low	Medium	High
Expenditures, Mcal ME/yr			
Cow	6110	6660	6930
Calf	1040	940	950
Total	7150	7600	7880
Production, lb/yr	444	455	480
Efficiency			
Biologic, lb/Mcal ME	.062	0.060	.061
Economic, $/energy, $	4.47	4.31	4.38

Adapted from Montaño-Bermudez and Nielsen, 1990.

As nutrient costs decrease, economic efficiency rankings may change. Hereford or Hereford X Angus X Charolais X Simmental or Hereford X Angus X Holstein X Simmental cows (crossbreeds) raised under farming conditions typical of Michigan, and similar to some in Minnesota, were bred to calve from late January to late March and weaned in September (Ritchie et al., 1983). Cows grazed summer pastures from May to September and were fed byproducts such as oat straw, old crop hay, haylage and green chop from September to January 15. Cows were drylotted from January 15 through May 26 and fed alfalfa-grass hay and/or haylage and sorghum sudan silage. After calving, crossbreeds were full-fed corn silage, while Hereford cows received haylage and corn silage. Although conception rates were similar (Table 4), and winter weight loss and winter energy expenditure were lower for Hereford cows, weaned weight at 205 d was 42% heavier for calves from crossbred cows. Therefore, income over feed cost/cow was $23.05 more for crossbreeds.

Table 4. Biologic and economic efficiency for Hereford or large-frame crossbred cows under a crop byproduct form operation

Item	Hereford	Crossbred	Difference
Cow BW in Fall, lb	950	1119	169
Conception rate, %	86.9	87.7	.8
Winter BW gain, lb/cow	-23	-48	-25
Winter TDN, lb/cow	1796	2654	768
Winter feed cost, $/cow	103.79	147.41	43.62
205-d weaned weight, lb	389	552	163
Annual TDN, lb/cow	4288	5738	1450
Annual TDN, $/cow	244	327	83
Weaned calf/cow wintered, lb	341	492	151
Calf value/cow wintered, $	238.7	344.4	105.70
Calf value-TDN cost, $	-5.72	17.33	23.05

Adapted from Ritchie et al., 1983.

Economic efficiency has been simulated for herds "reconstructed" from biological data obtained from various studies. One such simulation (Table 5; Bourdon and Brinks, 1987) involved a base scenario that represented standard ratios of prices received for cull cows and fed animals and no debt on land or cattle under range conditions (Colorado). Evaluation considered management of calves through a finishing period to a condition-constant end point of 30% empty body fat on an 85% TDN diet. Cows were simulated to calve in the spring and were fed supplemental hay from December or January through April. First-calf heifers were fed concentrate as well. Results from this simulation indicated that for cows of similar milk potentials, large cows were more biologically efficient, followed by medium and small cows. Under standard cost/price relationships, economic efficiency favored large breeds followed by medium and small cows. When hay costs were doubled (purchased hay), medium size cows were favored, followed by large and small cows. Under expensive feedlot costs (double processed feed costs), medium-sized cows were favored over large and small cows. For some unclear reason, total hay consumption by small-sized cows was high relative to production. This may be due to larger herds simulated for small cows and their low output/cow unit.

In a similar simulation for a spring-calving herd representative of the Southeastern U.S., cows of Hereford (HER), Charolais (CHR), Limousin (LIM), Angus (ANG) and Simmental (SIM) breeds were evaluated at weaning (Lamb et al., 1992a), or after a finishing period (Lamb et al., 1992b). Rankings, from most to least efficient (input cost Mcal ME or $/lb steer weight equivalent), were HER>ANG>LIM>CHR>SIM and SIM>CHR=HER=LIM>ANG for biologic and economic efficiencies, respectively, to weaning (Lamb et al., 1992a). Therefore, at weaning, economic efficiency simulation favored larger, heavy milking cows and large cows over small cows -- almost the opposite of biologic efficiency rankings. For biologic and economic efficiency simulation, including a finishing period, various end-points and equations were utilized. Two scenarios were chosen from this paper (Lamb et al., 1992b) that simulated sale of finished cattle at low choice (quality grade-based) or a given carcass weight (633-lb weight-based). Rankings (highest to lowest) were HER>CHR>LIM>ANG>SIM and HER>ANG>LIM=CHR>SIM for biological efficiency (Mcal ME/carcass weight) under choice- and weight-based marketing scenarios, respectively. Within these marketing scenarios, economic efficiency presented, from that simulated in the paper, were input costs/lean value(lean-value-based marketing) or carcass value (carcass-value-based marketing). When lean-value based marketing was simulated, choice- and weight-end point marketing resulted in efficiency (highest to lowest) rankings of HER>CHR>SIM>LIM>ANG and CHR=LIM>SIM>HER>ANG, respectively. When carcass-value based marketing was simulated, choice- and weight-end point marketing resulted in efficiency (highest to lowest) rankings of HER>CHR=SIM=LIM>ANG and ANG=HER>CHR=LIM>SIM, respectively. Therefore, although efficiency rankings varied according to marketing and end-point scenarios, it is apparent that British breeds may improve system efficiency under quality grade end-point scenarios regardless of marketing scenario and under carcass-value-based marketing with a weight end-point scenario, while Continental breeds may improve system efficiency under lean-value-based marketing with a weight-end point scenario.

Table 5. Simulated efficiency of genotypes with different mature sizes

				Biological efficiency		Standard cost		Doubled hay cost		Doubled concentrate cost	
Mature size, lb	Management system	Herd size	Total EBW[a] production, ton	TDN[b]/ EBW	Rank	Net profit, $	Rank	Net profit, $	Rank	Net profit, $	Rank
935	Yearling	284	96.7	10.69	3	15,990	3	-20,157	3	-11,336	2
1155	Yearling	204	88.3	10.35	2	18,825	2	-2,552	1	-9,986	1
1375	Yearling for heifers, weanling for steers	222	101.3	9.87	1	24,510	1	-4,973	2	-15,819	3

[a] EBW - empty body weight.
[b] TDN = total digestible nutrients.

Adapted from Bourdon and Brinks, 1987.

Both simulations presented rely heavily on the assumption that feed requirements are met to maintain reproductive performance. This implies that sufficient feed will be available on an as-needed basis for cattle; therefore, reproductive performance is only affected by inherent breed differences. In practice, some cows may not be able to meet their requirements from harvested and byproducts feeds presented to them because fiber content may not permit maximum intake. If consideration is made of this assumption, then simulations are helpful in evaluating possible trends to differentiate breeds for a given marketing purpose -- weaning or slaughter. This is important, as some measures of biologic, or even economic efficiency at weaning, may not take into consideration desirability of weaned calves (i.e., carcass size, tenderness and degree of fatness; Kattnig et al., 1993).

The Beef Improvement Federation Systems Committee (BIF, 1986) assembled Table 6 to summarize results from live animal and simulation studies evaluating cow size and milk production potential and profitability. Values presented represent the committee's recommendations for optimal genotypes for six traits under six environmental conditions. Environments were categorized by level of feed availability and level of stress (heat, cold, parasites, disease, mud and altitude). This permits almost all environments to be grouped into a manageable number of categories. The traits required to cope with the environments represented are traits associated with mature size, adaptability to stress and potential to store energy. Although these recommendations lean heavily toward managing the cow herd and include indirect consideration of growth potential (mature size) and lean yield, economic considerations must be factored in by its users. For instance, in situations where calf prices command a premium because of the time of weaning, or otherwise high demand, a step up to a greater mature size or higher milk yield potential for the specified conditions may be profitable.

Within-herd economic efficiency. Data discussed so far considered differences in economic efficiency between breeds only. Within a herd, there may be sufficient variation to select for biologically and economically efficient cow types (Taylor et al., 1986; DiCostanzo et al., 1990). Additionally, heritability estimates for maintenance requirements within herd may be at least .3 (Andersen, 1980; Carstens et al., 1989).

Within a herd, cows differed in biologic efficiency (DiCostanzo et al., 1991). Differences in biologic efficiency were related to amount of protein mass; cows having greater protein mass had higher maintenance requirements and lower biologic efficiency. Surprisingly, cows having higher maintenance requirements also weaned 31 lb lighter calves over approximately five calvings. This would indicate that within a herd, selection for cows weaning heavier calves may result in indirect selection for biologically efficient cows.

Although body condition was associated with energy requirements (Thompson et al., 1983; DiCostanzo et al., 1990; Ortigues et al., 1993a), it was difficult to establish a consistent link between an observed trait, other than calf weaning weight, and biologic efficiency (DiCostanzo et al., 1991). However, cows were characterized for their biologic efficiency in that study based on whether they maintained, gained or lost body weight during a feed restriction period. This would indicate that when natural conditions do not permit feeding above maintenance requirements, cows gaining body weight may be considered above average in biologic efficiency.

Table 6. Optimal genetic potentials for cattle in various production environments and breed roles[a]

Production environment		Traits					
Feed availability	Environmental stress[b]	Milk production	Mature size	Ability to store energy[c]	Adaptability to stress[d]	Calving ease	Lean yield
High	Low	M to H	M to H	L to M	M	M to H	H
	High	M	L to H	L to H	H	H	M to H
Medium	Low	M+	M	M	M	M to H	M to H
	High	M?	M	M	H	H	M
Low	Low	L to M	L to M	H	M	M to H	M
	High	L	L	H	H	H	L to H
--- Breed role in terminal crossbreeding systems ---							
Maternal		L to H	L to M	M to H	M to H	H	L to M
Paternal		L to M	H	L	M to H	M	H

[a] L = low; M = medium; H = high.
[b] Heat, cold, parasites, disease, mud, altitude.
[c] Ability to store fat and regulate energy requirements with changing (seasonal) availability of feed.
[d] Physiological tolerance to heat, cold, parasites, disease, mud and other stresses.

BIF, 1986.

Management Strategies

From the previous discussion of live animal results and simulations, it is quite clear that nutrient requirements of the cow and calf must be met to permit full expression of the herd reproductive and growth rates regardless of size. It is also evident that economic efficiency of large-frame or heavy milking breeds depends on their ability to wean a heavier calf consistently. Based on this observation, a simulation of cows of various mature sizes (Table 7; 1100, 1430 and 1760 lb) was made. Nutrient requirements for maintenance, gestation, lactation and calf growth were derived from NRC (1984). Cows were assumed to have similar lactation yield potentials. Cows were simulated to graze summer pastures (.84 Mcal ME/lb DM) rented at $9.30/cow-calf unit/mo for 5 mo followed by a drylot period (215 d). During the drylot period, hay ($40/ton; .79 Mcal ME/lb DM) was fed. Cows were simulated to maintain body weight throughout the year, breed (100% conception rate) and wean a calf at 210 d (3141 lb milk yield). Using these assumptions, additional weaning weight required to offset increased maintenance costs were calculated unadjusted (Table 8) and adjusted (Table 9) for salvage value of the cow ($50/cwt). From this simple exercise, it is apparent that heavier cows must wean calves that are 4 lb heavier for each additional 100 lb mature size when calf prices are between $90 and $100/cwt, and 5 lb heavier for each additional 100 lb mature size when calf prices are between $70 and $85/cwt.

Table 7. Simulated annual energy and dollar expenditures for beef cows of different weights

	Cow BW, lb		
Annual expenditure	1100	1430	1760
Maintenance			
Mcal ME	5995	7299	8529
$	140.9	171.6	200.5
Gestation			
Mcal ME	448	448	448
$	13.4	13.4	13.4
Lactation			
Mcal ME	1008	1008	1008
$	35.4	35.4	35.4
Calf growth			
Mcal ME	995	1184	1376
$	12.4	14.7	17.1
Total			
Mcal ME	8447	9940	11,361
$	202	235	266

Table 8. Additional weaning weight required to offset greater maintenance costs of large-size cows[a]

Calf price, $/cwt	1430 lb or +$30/yr	1760 lb or +$60/yr
60	50	100
65	46	92
70	43	86
75	40	80
80	38	75
85	35	71
90	33	67
95	32	63
100	30	60
105	29	57

[a] Unadjusted for salvage value of cow.

Table 9. Additional weaning weight to offset greater maintenance costs of large-size cows[a]

Calf price, $/cwt	1430 lb or +$12.50/yr	1760 lb or +$50/yr
60	21	42
65	19	38
70	18	36
75	17	33
80	16	31
85	15	29
90	14	28
95	13	26
100	12.5	25
105	12	24

[a] Adjusting for salvage value of cow ($50/cwt) over six calvings.

Although a great deal of information regarding cow size and efficiency has been generated through the years, producers operating "less-than-desired" breeds" often will wonder what to do with it. From the previous discussion, a producer operating a large-mature-size cow-calf herd in semi-desert conditions may either disregard the information and continue his/her plans or take the information as the only solution and immediately switch the cow herd to a more economically efficient one. Both of these responses would probably prove economically inefficient and little benefit would be derived from this information. From the previous discussion producers should be encouraged to:

1. evaluate the current economic status of their herds -- their economic efficiency may already meet their business and personal goals;
2. if not, determine if cow size is a major problem;
3. if cow size is a problem, determine what cow size is recommended for their economic and nutritional environment;
4. if keeping current cow size is a personal goal, then strategic supplementation and management to maintain high reproductive rates is highly recommended;
5. if keeping the current breed is a personal goal, selecting cows that wean heavier calves consistently every year may improve economic efficiency, or;
6. selecting for efficient cows; when fed at maintenance levels, biologically efficient cows may tend to maintain or gain weight.

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