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## Introduction

Since the introduction of new germ plasm resources into the U.S. beginning in the early 1960's, the influence of biological types on various aspects of beef production have been evaluated extensively. Traits studied include preweaning calf performance, postweaning growth and feed efficiency, carcass characteristics, puberty and other reproductive characteristics, and milk production, to name a few. In general, however, most of the research efforts have concentrated on the areas involving the growing animal and/or its carcass characteristics. That is, output characteristics of the various biological types of cattle have been of primary interest to researchers. Much less effort has been expended to quantify the impact various biological types of cattle may have on input components of beef production. There has been, in particular, a dearth of information regarding the influence of biological type on the feed requirements of mature cows, even though various researchers have noted that the feed required to replenish and maintain the cow herd constitutes a major portion (65 to 75%) of the feed resources required for beef production. Differences among biological types in the feed required to maintain the cow herd may have a substantial impact on the efficiency of beef production. Thus, in this report, we will attempt to summarize our data relative to the effect of biological type on feed energy requirements of mature cows.

## Procedure and Results

A series of studies was initiated to develop greater understanding of energy utilization and requirements of mature cows of various biological types during the production cycle. A study was designed to quantify the metabolizable energy (ME) required to maintain wt of mature cows of four biological types during a production cycle when fed forage diets of differing qualities. Diets consisted of 70% brome haylage: 30% alfalfa haylage; 35% brome haylage: 65% alfalfa haylage; and 100% alfalfa haylage. Dry matter contents of the diets were determined and ME contents calculated. Four biological types of cows were represented by Angus or Hereford (AHX), Charolais (CX), Jersey (JX), or Simmental (SX) sired cows produced from Angus or Hereford dams. These cows were chosen as representatives of cows having genetic potential for moderate size, moderate milk production (AHX); large size, moderate milk production (CX); moderate size, high milk production (JX); and large size, high milk production (SX). All cows were mated to Brown Swiss bulls. Cows were individually fed each of the three diets indicated above by use of Calan-Broadbent electronic headgates. The diets were fed from about 100 days prepartum until weaning at 196 days postpartum. Weights of the cows were recorded at the beginning, end, and at approximately 28-day intervals during the study. Daily feed intakes were summed over each wt interval. Milk production of each cow was determined on days 14 and 28 postpartum and at 28-day intervals during the remainder of the study. Calves were creep fed throughout the study.

A quadratic regression was fit to the wt of each cow; initial and final wt were calculated from the regression as the wt at day 0 and 297, respectively. Empty body wt (EBW) at each of those times was calculated as:

$$EBW = 0.88 \times \text{liveweight} - 16.34.$$

Total ME intake was calculated as the sum of the feed intake during the 297-day study times the appropriate dry matter and ME contents of the diet. To estimate the ME required for zero wt change during the 297-day period, actual ME intakes were adjusted for empty body wt changes. Daily milk yield at the times specified above were used to estimate parameters of a lactation curve for each cow with the empirical equation:

$$Y(n) = n/ae^{kn}$$

where Y(n) is the daily milk yield during the nth week postpartum and a and k define the shape of the lactation curve. Total milk yield was calculated by integrating the equation over the interval from 0 to 25 wk postpartum. Effects of sire breed and dam breed of the cow, diet, and the two-way interactions on the response variables were evaluated by analysis of variance. The two-way interactions were not significant for any variable, and were thus deleted from the final statistical model.

Lactation curves of the four biological types of cows are depicted in Figure 1. These curves indicate milk yield at peak lactation was greatest for SX cows and least for AHX cows. Rates of decline in milk yield after peak yield was greatest for CX cows and least for AHX and JX cows. Initial empty body wt, daily wt change, total milk yield, and ME intakes were significantly ($P < .10$) influenced only by sire breed. Means for sire breed groups are presented in Table 1. The CX and SX cows were heavier than JX and AHX cows, and the SX and JX cows produced greater quantities of milk than AHX or CX cows, as anticipated. Although not significantly different, rates

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**Table 1—The influence of biological type of cow (sire breed) on initial empty body weight (IEBW), average daily gain (ADG), milk yield, and metabolizable energy (ME) intakes during a production cycle[a]**

| Sire breed | N | IEBW (lb) | ADG (lb) | Milk yield (lb per 25 wk) | ME intake Actual | ME intake Adjusted[b] |
|---|---|---|---|---|---|---|
| Angus, Hereford | 14 | 1,087[cd] | -.084 | 2,685[c] | 6,694[c] | 6,885[c] |
| Charolais | 15 | 1,175[e] | -.075 | 2,862[cd] | 7,293[cd] | 7,467[c] |
| Jersey | 14 | 1,056[c] | -.123 | 3,314[cd] | 7,115[a] | 7,422[c] |
| Simmental | 17 | 1,133[de] | -.205 | 3,448[d] | 8,274[d] | 8,691[d] |

[a]The production cycle began about 100 days prepartum and ended about 196 days postpartum.
[b]Actual ME intake adjusted to zero empty body wt change.
[cde]Means with different superscripts are significantly different.

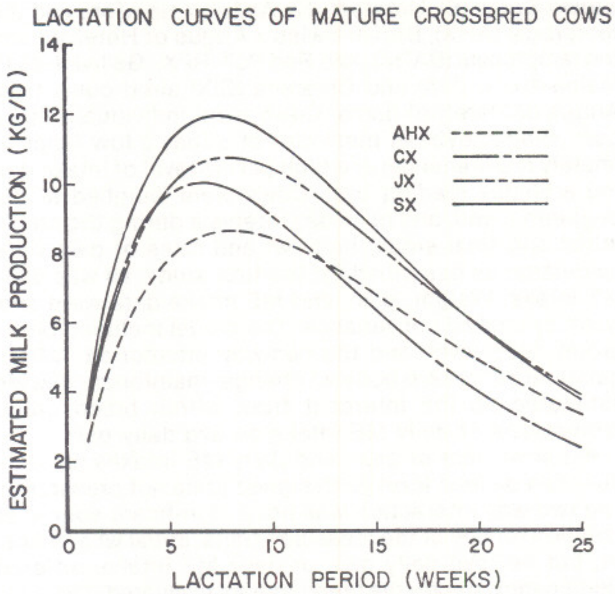


**Figure 1**—Lactation curves of mature crossbred cows of different types.

of gain tended to be greater for breed crosses having the lower milk yields. The small (5% or less) adjustments of actual ME intakes for wt changes tended to favor AHX and CX cows over the higher milk-producing types. Inspection of ME intakes adjusted to zero wt change during the 297-day interval indicate CX, JX, and SX cows required about 108, 108, and 126% of that required by AHX cows.

Differences relative to the AHX cows appear to be due to size (CX), and size and level of milk production (JX and SX).

In a subsequent study, mature, non-pregnant, non-lactating AHX, CX, JX, and SX cows were used. In each of 2 yr, cows of each type were fed a corn silage-soybean meal diet at either a low, medium, or high level of intake. Cows were fed individually each day for 140 days and feed intakes and wt changes were recorded. Body composition was estimated by deuterium oxide dilution procedures at the beginning and end of the study. Empty body energy change during the 140-day study was calculated as the difference between final and initial empty body energy contents. Maintenance (zero empty body energy change) requirements of each type of cow were estimated by regression analysis.

Results from these analyses (Table 2) indicate maintenance requirements of mature, non-pregnant, non-lactating cows differed among biological types. When expressed as kcal ME/kg$^{0.75}$/day, SX cows had the highest maintenance requirements followed by JX cows, and the CX and AHX cows had the lowest maintenance requirements. When the results were expressed on a daily basis, however, AHX and JX cows had similar requirements; CX cows were intermediate; and SX cows had the highest requirements. In these results, like those in the first study, maintenance requirements appeared to reflect both size and milk production potentials of the cows, even though they were neither pregnant nor lactating during the study.

Annual ME requirements for maintenance (Table 3) were calculated by multiplying estimates of daily requirements by 365. Data on birth wt of calves produced by mating mature (4 to 8 yr) cows of these types to Brown Swiss bulls were obtained from results of the Germ Plasm Evaluation program. The ME requirements for gestation were estimated and scaled by calf birth wt. Estimates of the milk yield of cows of the same breed crosses during a 25-wk lactation period (Table 1) were used to estimate ME requirements for milk production, assuming 1.06 Mcal ME was required to produce each lb milk. Annual ME requirements were calculated as the sum of the requirements for maintenance, gestation, and lactation.

It should be noted that estimates of annual ME requirements reported in Table 3 should not be directly compared to the values reported in Table 1 because of the different time intervals (297 *vs* 365 days) and the differing qualities of the diets fed (alfalfa: brome *vs* corn silage:soybean meal). However, the ranking of the cows of the four sire breeds was remarkably similar between the two studies. Results shown in Table 3 indicate CX, JX, and SX cows had annual requirements 109, 106, and 128% of those of AHX cows, whereas comparable values from the first study were 108, 108, and 126%, respectively. Within each of the cow types, maintenance requirements accounted for 71 to 75% of the total annual

**Table 2—Mean initial empty body weight (IEBW), metabolizable energy intake (MEI), daily body energy gain (EG), and maintenance requirements of cows of four sire breeds**

| Cow sire breed | N | IEBW (lb) | MEI (kcal/kg$^{.75}$/day) | EG (kcal/kg$^{.75}$/day) | Maintenance requirements (kcal/kg$^{.75}$/day) | (Mcal day) |
|---|---|---|---|---|---|---|
| Angus/Hereford | 22 | 1,038 | 180 | 21.3 | 130 | 14.0 |
| Charolais | 18 | 1,267 | 166 | 12.0 | 129 | 15.0 |
| Jersey | 17 | 923 | 197 | 15.9 | 145 | 14.2 |
| Simmental | 21 | 1,151 | 175 | 4.3 | 160 | 17.9 |

**Table 3—Annual metabolizable energy (ME) requirements of cows of four sire breeds**

| Cow sire breed | Maintenance (Mcal/yr) | Calf birth[a] wt (lb) | ME for[b] gestation (Mcal) | ME for[c] lactation (Mcal) | Total ME required (Mcal/yr) |
|---|---|---|---|---|---|
| Angus/Hereford | 5,010 | 91 | 529 | 1,300 | 6,839 |
| Charolais | 5,475 | 98 | 573 | 1,380 | 7,428 |
| Jersey | 5,183 | 83 | 484 | 1,600 | 7,267 |
| Simmental | 6,533 | 93 | 562 | 1,660 | 8,755 |

[a]Based on data from the MARC Germ Plasm Evaluation Program; calves were all sired by Brown Swiss bulls; N = 431 to 624.
[b]Calculated by scaling the energy requirements for pregnancy by calf birth wt.
[c]Calculated from the milk yield estimates of cows of these types (Table 1) assuming 1.06 Mcal ME/kg milk.

requirements for energy, whereas gestation and lactation accounted for 6.4 to 7.7% and 18.6 to 22.0%, respectively. This demonstrates the relative contribution of maintenance requirements to annual cow energy requirements.

In a third study, cows sired by Red Poll (RX), Brown Swiss (BX), Gelbvieh (GX), Maine-Anjou (MX), or Chianina (CiX) bulls and out of Angus or Hereford dams were fed to maintain their initial body wt during a 138- or 139-day lactation period commencing at about 45 days postpartum. Cows raising Simmental sired calves were assigned to replicated pens (2 pens/yr) of 12 cow-calf pairs/pen/breed group. Cows were fed a corn silage-based diet and were weighed at 14-day intervals. Feed allowances were adjusted at those times in an attempt to achieve zero wt changes. Milk production was estimated by weigh-suckle-weigh procedures. Calves were creep fed each yr, and pen creep feed consumption was recorded. Calves were weighed at the beginning and end of the study each yr, as well as at the time of milk yield determinations. Metabolizable energy consumption of the dams was adjusted to zero biweekly wt change by regression procedures.

Results of this study (Table 4) indicated significant cow breed effects on initial and final calf wt, but not on calf ME consumption. Initial and final cow wt differed among the cow breed groups, as did avg daily milk production. The ME required for zero wt change differed among the cow types during the 138 days of lactation evaluated. The observed differences reflected differences in cow size and milk production, as observed in previous studies.

An additional study was conducted using mature, non-pregnant, non-lactating cows from cycle II of the GPE program plus cows from a three-breed diallel. The breeds and breed crosses used in the study included Angus (A), Brown Swiss (B), Hereford (H), Angus x Hereford and the reciprocal (AHX), Brown Swiss x Angus or Hereford and the reciprocals (BAHX), and Red Poll (RPX), Gelbvieh (GX), Maine-Anjou (MX) and Chianina (CiX) sired cows from Angus or Hereford dams. Cows were individually fed a corn silage-soybean meal diet at either a low (approximately maintenance) or a high (*ad lib*) level of intake during a 96-day feeding trial. Cows were weighed at the beginning, end, and at 14-day intervals during the study. Initial and final empty body wt and rates of gain were calculated as described for the first study, as was daily ME intake. Weight, gain, and ME intake data were analyzed by analysis of variance. The model included breed group, feed level, and the two-way interaction. ME requirements for zero body wt change (maintenance) were estimated as the intercept from within breed group regressions of daily ME intake on avg daily gain.

Final wt, rate of gain, and daily ME intakes were influenced by feed level as designed (data not presented). The two-way interaction was not a significant source or variation for any of the measured traits. Initial wt and final wt, but not avg daily gain or daily ME intake, differed significantly among the breed groups evaluated. The daily ME required for zero body wt change (maintenance) differed among the breed groups. Ranking on the basis of daily feed required to maintain body wt of non-pregnant, non-lactating crossbred cows was similar to ranking of the same breed crosses during lactation. In general, differences in maintenance requirements reflected differences in cow size and milk production potential. In addition, although not rigorously analyzed, maintenance of crossbred cows tended to be slightly lower than the avg of straightbred cows. This observation warrants further study.

**Table 4—Weights and metabolizable energy intake of cows of different biological types and their progeny from 45 to 183 days postpartum**

| Cow sire breed[a] | Calf wt (lb) | | Calf ME intake from feed | Milk yield | Cow wt (lb) | | Cow ME intake[b] |
|---|---|---|---|---|---|---|---|
| | Initial | Final | (Mcal/day) | (lb/day) | Initial | Final | (Mcal/day) |
| Angus/Hereford | 175 | 509 | 5.7 | 15.1 | 1,111 | 1,157 | 24.9 |
| Red Poll | 197 | 542 | 5.5 | 17.9 | 1,032 | 1,056 | 26.2 |
| Brown Swiss | 200 | 556 | 5.3 | 21.0 | 1,100 | 1,124 | 28.6 |
| Gelbvieh | 202 | 549 | 5.1 | 19.8 | 1,144 | 1,164 | 28.6 |
| Maine-Anjou | 206 | 560 | 5.3 | 18.5 | 1,221 | 1,254 | 27.4 |
| Chianina | 200 | 540 | 5.3 | 14.6 | 1,221 | 1,239 | 28.3 |

[a]Cows were produced from Angus or Hereford dams; all calves were sired by Simmental bulls.
[b]Cow ME intakes were adjusted to zero wt change by regression analysis.

**Table 5—Least-squares means empty body wt, rate of gain, metabolizable energy (ME) intake, and ME required to maintain body wt on non-pregnant, non-lactating cows of several breeds or breed crosses**

| Breed or breed cross | N | Empty body wt (lb) | | Gain | ME intake | Maintenance[a] | |
|---|---|---|---|---|---|---|---|
| | | Initial | Final | (lb/day) | (Mcal/day) | Mcal/day | kcal/kg$^{.75}$/day |
| Angus (A) | 12 | 875 | 972 | 1.01 | 21.8 | 12.7 | 138 |
| Brown Swiss (B) | 12 | 941 | 1,030 | .90 | 22.6 | 17.9 | 184 |
| Hereford (H) | 11 | 919 | 981 | .66 | 20.9 | 13.0 | 137 |
| AH X | 20 | 983 | 1,078 | .99 | 21.0 | 12.0 | 119 |
| BAH X | 35 | 944 | 1,043 | 1.01 | 22.9 | 15.3 | 156 |
| Red Poll X[b] | 22 | 891 | 979 | .95 | 21.4 | 13.0 | 149 |
| Gelbvieh X | 23 | 967 | 1,041 | .75 | 21.6 | 17.2 | 174 |
| Maine-Anjou X | 24 | 1,045 | 1,140 | .99 | 23.7 | 14.9 | 142 |
| Chianina X | 23 | 1,030 | 1,116 | .90 | 22.4 | 16.4 | 158 |

[a]Daily maintenance (ME required for zero body wt change) was estimated as the intercept of the linear or quadratic regression, within breed or breed cross, of daily ME intake on avg daily empty body wt gain. Estimates of daily maintenance requirements were scaled by average empty body wt $^{.75}$ to adjust for cow size.
[b]Red Poll, Gelbvieh, Maine-Anjou, and Chianina crossbred cows were produced from Angus and Hereford dams.

The estimates of ME required for maintenance were scaled by avg empty body wt raised to the .75 power (MBS) to adjust for cow size differences. No estimates of variation are available due to the procedures used, thus the values presented in Table 5 should be viewed with some caution. Within the straightbred cows, Brown Swiss had higher maintenance requirements than Angus or Hereford cows. Within the crossbred populations evaluated, AHX cows had the lowest and GX, CiX, and BAHX cows tended to have the highest maintenance requirements per kg MBS. These results were consistent with those observed in previous studies.

**Discussion**

As noted previously, feed required for cow maintenance is a major component of the feed resources required for beef production. Observations reported here suggest that maintenance accounts for 71 to 75% of the ME required by the cow during the production cycle. Maintenance has also been shown to account for 30 to 50% of the ME required by growing-finishing cattle and for about 50 to 60% of the ME required by replacement heifers. Thus, it is evident that maintenance requirements are a major component of the feed energy required for beef production. Results from the four studies presented suggest that biological type of the cow may have a substantial impact on the ME required for maintenance (wt or energy stasis). Estimates of the ME required for maintenance differed among types evaluated within a study by as much as 50%. Obviously, differences of that magnitude may have a substantial impact on the efficiency of beef production. As a result, it is appropriate that attempts be made to quantify sources of variation in energy expenditures for maintenance.

Data reviewed previously indicated generally positive relationships between estimates of maintenance requirements and measures of genetic potential for production such as rate of growth or milk production. A plot of estimates of maintenance requirements for non-pregnant, non-lactating cows *vs* mean milk yield at peak lactation of cows of the same breeds or breed crosses (Fig. 2) supports that observation. Those results suggested that maintenance requirements increased about 6.16 kcal/kg$^{.75}$/day for each kg increase in milk yield at peak lactation (2.8 kcal/kg$^{.75}$/day/lb increase in peak milk yield). They further suggested that about 50% of the observed variation in maintenance requirements in the populations evaluated was attributable to variation in milk production potential as measured by weigh-suckle-weigh procedures.

Taylor and coworkers, working in Scotland, have also noted substantial differences in maintenance requirements of cows of different types. Their data indicated maintenance requirements of Angus, Hereford, Dexter, British Friesian, and Jersey to be 123, 126, 136, 150, and 150 kcal/kg$^{.75}$/day, respectively. They observed a significant positive relationship between maintenance requirements and total or peak milk yield. About 70% of the variation in maintenance requirements was associated with variation in milk production. After an extensive review of the literature, they concluded that "most of the variation in published estimates (of maintenance requirements) for mature fed cows is, therefore, explained by breed differences linked to lactability."

Further expansion of this concept may be appropriate. Maintenance appears to increase with increased potential for growth rate, as well as with increased potential for milk production. For example, the data of Frisch and

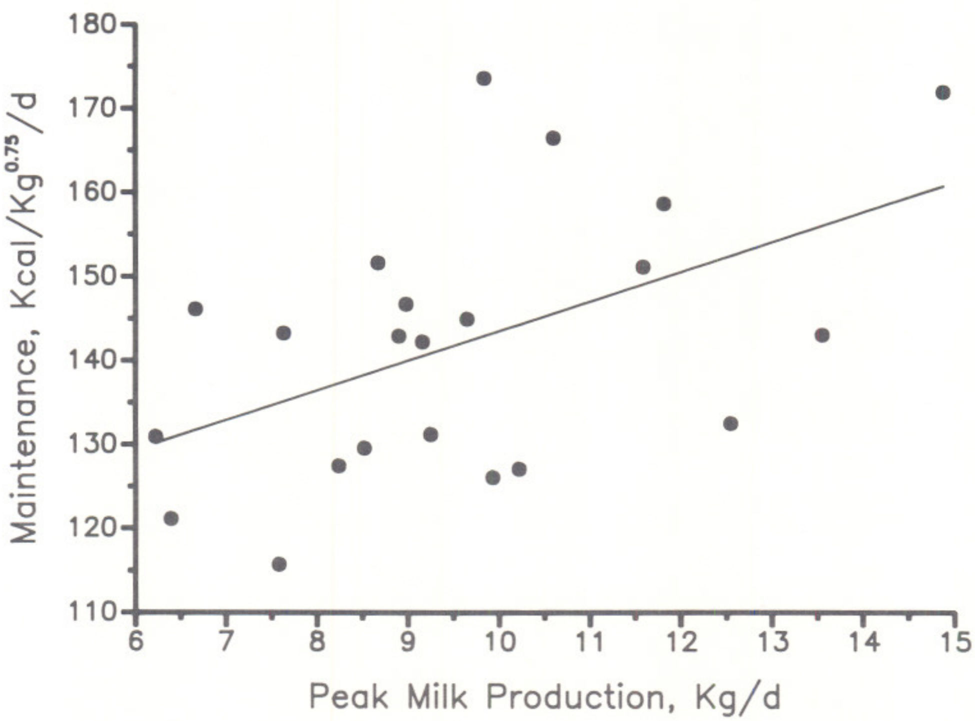


**Figure 2**—Regression of maintenance requirements (kcal/kg$^{.75}$/day) of non-pregnant, non-lactating cows on milk production at peak lactation (kg/day); maintenance = 70.5 (± 16.2) + 6.16 (± 1.38) * milk, $R^2$ = .50, N = 22.

Vercoe indicated Brahman and Africander differed from Hereford x Shorthorn by having a lower metabolic rate, lower growth rate, and lower feed intake. Rogerson similarly noted lower fasting heat production and lower growth rate of Boran as compared to Hereford steers. We noted lower maintenance requirements of heifers as compared to bulls and of Hereford as compared to Simmental growing cattle. Similarly, several reported studies indicate that dairy breeds are more productive than beef-dairy crosses and beef-dairy crosses to be more productive than beef breeds with the higher productivity associated with higher fasting energy expenditures or maintenance requirements in each case. Analysis of data reported from several studies indicated a positive, linear increase in maintenance requirements with productivity of genotype.

Variation in maintenance requirements may reflect responses to the environmental conditions in which breeds of cattle evolved or were selected. For example, in tropical grazing conditions, *Bos indicus* cattle generally have more wt gain than *Bos taurus* cattle. Conversely, under *ad lib* pen feeding, *Bos indicus* cattle generally consume less feed and gain wt less rapidly than *Bos taurus* cattle. It has been shown experimentally that selection for increased growth rate in an environment with high levels of heat, humidity, and parasites results in decreased fasting production. Selection for increased growth rate in a more ideal environment, on the other hand, is expected to result in increased mature size and fasting or maintenance energy expenditure. Thus, selection may result in a population of animals becoming highly adapted to a specific environment, but may render it less adapted to a different environment. Correlated responses to selection may also result in decreased adaptability to fluctuating environments. As a result, care should be taken to ensure synchronization of cattle type and the production environment.

## Conclusions

Data have been presented to indicate that maintenance requirements account for a large portion of the feed resources required for beef production, and that maintenance requirements appear to differ among various biological types of cattle. In general, there appears to be a positive association between genetic potential for productivity and maintenance requirements. Thus, in terms of improvement in beef production efficiency, there is an antagonistic relationship between productivity and feed requirements. Numerous other antagonistic genetic relationships between traits important to beef production, such as growth rate *vs* birth wt and dystocia, retail product *vs* marbling, retail product growth rate *vs* age at puberty or mature size, have limited improvement in beef production efficiency. As noted by Cundiff, it is clear that no one breed or type excels in all characteristics of economic importance to the beef industry, nor is it reasonable to expect simultaneous improvement in all desired characteristics by selection. Use of various crossbreeding systems that exploit complementarily, heterosis, and the opportunity to match genetic resources to the production environment provide the most effective available means to manage trade-offs from genetic antagonisms.