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A SYSTEM OF PREDICTING THE FEEDLOT PERFORMANCE OF GROWING AND FINISHING CATTLE

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Introduction

Profitable cattle feeding requires the use of sound feed principles, astute day-to-day management and a close estimation of costs and expected returns. The central key to this goal is an accurate prediction of actual cattle performance under a given set of conditions. Cattlemen and researchers have long recognized that there are many biological and environmental factors which have a substantial impact on feedlot performance. The objective of this paper is to describe a mathematical system, based upon an extensive summary of North American studies, which will account for these important variables through the use of appropriate adjustment factors so that payweight to payweight feedlot performance can be accurately predicted under a variety of midwest field conditions.

The California Net Energy System (CNES) is used as the starting point and foundation for feedlot projection.

The CNES has become the most widely used energy system for ration formulation and gain projection of feedlot cattle in the United States, including its use as the base for N.R.C. requirements (Lofgreen and Garrett, 1968). While investigators have questioned certain aspects of the system's conceptual basis (e.g., Kromann, 1973a; Knox and Handley, 1973; Moe and Tyrrell, 1973), its predictive capability appears to be superior to other systems when evaluated across a wide range of situations.

The CNES framework needs further generalization since it was developed using average frame size British breed cattle receiving a growth stimulant and fed in a thermal neutral environment. The objective of this paper is to generalize the CNES by using suitable adjustment factors to take into account alternative frame sizes, breeds, sexes and ages, varied body conditions due to previous nutritional treatment, the use of various growth stimulants and feed additives, the associative effects of feedstuffs and various environments. The physiological effects of these factors are estimated using results from a variety of experiments. Dry matter intake equations are described, as are equations to predict quality and yield grades.

California Net Energy System

It is useful, prior to generalizing the CNES, to review its basic properties. The net energy requirement for maintenance is estimated as

(1) $NE_m^r = .077W^{.75}$

The authors have benefited from the conceptual suggestions and computational assistance of Roger Crickenberger, Department of Animal Science, North Carolina State University.

where NE_m^r is expressed in Mcal/day and W denotes the empty body weight in kilograms. The net energy requirement for gain is estimated for steers as

$$(2)\quad NE_g^r = (.05272G + .00684G^2)\ (W^{.75})$$

and for heifers as

$$(3)\quad NE_g^r = (.05603G + .01265G^2)\ (W^{.75})$$

where NE_g^r is expressed in Mcal/day and G (gain) is measured in kg/day. Alternatively, given the net energy available for gain (NEFG) and weight, equations 2 and 3 can be solved to project daily gain. For steers

$$(4)\quad G = \frac{\sqrt{.002779 + (.02736)\ (NEFG/W^{.75})} - .05272}{.01368}$$

and for heifers

$$(5)\quad G = \frac{\sqrt{.003139 + (.0506)\ (NEFG/W^{.75})} - .05603}{.0253}$$

The gain prediction model can be completed with the addition of an equation which will predict daily dry matter intake. We have

$$(6)\quad FFM = NE_m^r/NE_m^a,$$

$$(7)\quad FFG = DMI - FFM, \text{ and}$$

$$(8)\quad NEFG = (FFG)\ (NE_g^a)$$

where FFM is the feed required for maintenance, kg/day, FFG is the feed available for gain, kg/day, DMI is the daily dry matter intake, kg/day, NEFG is the net energy for gain, MCal/day, NE_m^a is the net energy value of the ration for maintenance, Mcal/kg feed and NE_g^a is the net energy value of the ration for gain, Mcal/kg feed. All values are on a dry matter basis.

A Generalization

The parameters used in this generalization were assembled on a component by component basis from specialized studies, literature reviews and on-going research. The model is described below, followed by sections describing the parameter estimates.

The net energy/kg of feedstuff for maintenance is

$$(9)\quad NE_m^a = (COND)\ (FA)\ (NE_m)$$

and for gain

$$(10)\quad NE_g^a = (COND)\ (FA)\ (NE_g)$$

where NE_m is the net energy value of feed for maintenance, Mcal/kg feed, NE_g is the net energy value of feed for gain, Mcal/kg feed, COND is an adjustment factor for previous nutritional treatment and FA is an adjustment factor for the use of antibiotics and/or Rumensin. The NE_m and NE_g values are also adjusted for associative effects.

The requirements component includes, for maintenance

$$(11)\ NE_m^r = (ENV)\ (BREED)\ (.077)\ (W^{.75}),$$

for gain projections of steers,

$$(12)\ G = \frac{\sqrt{.002779 + (.02736)\ [(NEFG)\ /\ (BREED)\ WE^{.75}]} - .05272}{.01368}$$

and for gain projections of heifers,

$$(13)\ G = \frac{\sqrt{.003139 + (.0506)\ [(NEFG)\ /\ (BREED)\ WE^{.75}]} - .05603}{.0253}$$

where ENV is an adjustment factor based upon environmental conditions, BREED is an adjustment factor for Holsteins relative to British and British x exotic crosses and WE is an adjusted (equivalent) weight, measured in kilograms, for frame size and the use of growth stimulants.

Nutrient Requirement Adjustments

Frame Size

The maintenance requirement (equation 11) is a function of actual body weight, while the gain requirement is a function of the proportion of fat and protein in the tissue gain. The latter is influenced by the frame size of the animal and the use of growth stimulants. For example, the net energy required per pound gain is lower at a particular weight for steers which will grade low choice at 1320 lb. than for ones which will reach that grade at 880 pounds. Our estimate of the NE_g^r per lb. gain for an 880-lb., small framed steer gaining 2.2 lb. per day is 2.86 Mcal; it is 2.13 Mcal for an 880-lb., large framed steer. Alternatively, the question may be asked, "At what weight do animals of various frame sizes have the same net energy requirement per pound of gain?" Our generalization is based upon the assumption that steers with the same empty body chemical composition in terms of percent fat and protein will have the same net energy requirement per pound of gain.

Table 1, based on work by Reid (1974), Ayala (1974) and Simpfendorfer (1974), gives an estimate of the weights at which animals of alternative frame sizes have equivalent percentages of protein and fat. If a steer differs from average frame, the weight at which an average framed steer is equivalent in body composition to him is used in gain projections (equation 12). For example, a 900-lb. steer would be used in the gain projection equation for a 720-lb., small framed steer and for a 1080-lb., large framed steer. Garrett (1976a) has suggested a similar procedure.

Table 1. Estimated Weights for Animals of Alternative Frame Sizes at Which the Proportion of Body Fat and Protein Are Similar[a]

	Shrunk Weight, Lb.									
Steers										
Small frame	400	480	560	640	720	800	880	960	1040	1120
Average frame	500	600	700	800	900	1000	1100	1200	1300	1400
Large frame	600	720	840	960	1080	1200	1320	1440	1560	1680
Heifers										
Small frame	330	390	460	530	590	660	720	790	860	925
Average frame	400	480	560	640	720	800	880	960	1040	1120
Large frame	470	560	660	750	840	940	1030	1130	1220	1315
	Chemical Composition, Percent of Empty Body Weight									
Fat[b]	14.9	17.2	19.5	21.8	24.2	26.5	28.8	31.1	33.3	35.6
Protein[b]	19.5	19.1	18.6	18.1	17.6	17.1	16.5	16.0	15.4	14.9

[a] Small, average and large frame steers reach a fatness of low choice, yield 3.0, in the weight range of 800-880, 1000-1100 and 1200-1320, respectively. The weights for heifers are 660-720, 800-880 and 940-1000, respectively.

[b] Fat and protein in the empty body were adapted from $\text{Fat} = -.61 + .037\ \text{EBG} + .000504\ \text{EBW}^2$ and $\text{Protein} = -2.418 + .235\ \text{EBW} - .00013\ \text{EBW}^2$, respectively (Reid, 1974; Simpfendorfer, 1974). EBW, empty body weight, fat and protein are measured in kilograms. Empty body weight typically ranges from 90% of shrunk weight at 500 lb. to 94% at 1050 lb. for an average framed steer (Fox, 1968; Simpfendorfer, 1974; Jesse *et al.*, 1976).

> "The (net energy for gain) requirements ... can be adjusted for particular groups of cattle if experience indicates adjustment is necessary. For example ... requirements for breeds maturing at heavier weights and some heavy short yearlings may be adjusted by multiplying (equation 2) by .92 or some other factor."

The results of the energetic model, when combined with a dry matter intake model based on equivalent weight, are consistent with data from several studies. It predicts a 0.6 lb. per day difference in daily gain between large and small framed steers with similar feed requirements per pound of gain when feedlot cattle are carried from comparable starting to endpoints in terms of body composition. This is consistent with experimental data where cattle of different mature sizes were compared (Brungardt, 1972; Klosterman, 1974; Crickenberger *et al.*, 1976; Harpster *et al.*, 1976).

Sex

Frame size variation in heifers is treated in the same fashion as with steers, except that the heifer gain projection (equation 13) is used. However, predicted heifer gains using the equivalent weight concept and the steer equation are within 2 to 4% of that predicted by the heifer equations.

Recent research suggests an adjustment for heifer "quality" may be needed. Klosterman and Parker (1976) found that heifer and steer herd mates were similar in feed efficiency when both were fed to the same body composition. In contrast, Harpster et al. (1976) reported that the feed efficiency of heifers which were rejected as herd replacements was 10% less than steers when fed to a similar composition. Genetics is only part of the reason for culling; other reasons for a lighter weaning weight include sickness, injury and poor nutrition leading to stunting.

In preliminary work, an adjustment of .84 has been used to arrive at an equivalent weight of bulls relative to steers; a bull is equivalent in body composition to a steer weighing 84% as much. Garrett (1976a) has suggested the NE_g requirement of bulls is 88% of the steer requirement at the same weight.

Breed

Adjustments in energetic efficiency were not made for alternative British breeds and for British x exotic crosses since research results suggest differences in postweaning feed efficiency are small when all are compared at the same stage of growth (Klosterman, 1974; U.S.M.A.R.C., 1976; Crickenberger et al., 1976; Harpster et al., 1976). An adjustment is warranted for Holsteins. Studies of Holsteins vs British breed cattle (Garrett, 1971; Ayala, 1974; Crickenberger et al., 1976) suggest that Holsteins are energetically less efficient, having a larger maintenance requirement and requiring more net energy per pound gain when compared at equivalent body composition. Other feeding trials suggest the feed efficiency of Holsteins and British cattle is similar when Holsteins are carried to the good quality grade (new grading system) vs choice for British cattle (e.g., Henderson, 1969). This is consistent with poorer energetic efficiency, particularly when one takes into account that Holsteins probably have a larger daily dry matter intake when compared on an equivalent weight basis. Our estimate of the breed effect multipliers is given in table 2.

Table 2. Estimated Impact of Breed on
Net Energy Requirements

	Multiplier	
	NE_m^r	NE_g^r
British	1.00	1.00
Exotic	1.00	1.00
British x exotic	1.00	1.00
Holstein	1.12	1.12
Holstein x British	1.06	1.06

Environment

The CNES was developed within a thermal neutral environment. Thus, it is necessary to adjust for the wide variety of environments which exist in North America where stress exists at least during part of the year. A scale from 1 to 7 is used to adjust the maintenance requirement for environment, based on housing studies at midwestern experiment stations (Hasbargen, 1967; Henderson and Geasler, 1968; Henderson, 1969; Petritz, 1972; Self, 1972, Smith and Hasbargen, 1975, Pherson _et al_., 1977). Typical values are given in table 3, with adjustments reflecting impacts over longer periods of time, e.g., 2 to 3 months.

Work needs to be extended to include an evaluation of the impacts of heat increment to determine if there are any interactions between environment and feeding systems. Brokken (1971), Webster _et al_. (1970), Lofgreen (1974), Young (1976) and Paine (1976) have conducted studies in this area.

Table 3. Estimated Impact of Environment on Net Energy Requirements

Scale value	Lot condition	Multiplier for NE_m^r
1	Outside lot with frequent deep mud	1.30
5	Outside lot, well mounded, bedded during adverse weather	1.10
7	No mud, shade, good ventilation, no chill stress	1.00

Growth Stimulants

Growth stimulants improve rate of gain and the conversion of feed into gain. Experimental data for the commonly used products are summarized in table 4. Most comparisons are for cattle on feed the same length of time. The mode of action of growth stimulants is not clear; apparently all are anabolic (Preston and Willis, 1974; Preston, 1975). The use of growth stimulants increases the weight at which the percent fat and protein in the empty body are similar to that of nontreated animals. DES, for a given number of days on feed, gives the largest improvement in daily gain. DES and Synovex-S treated cattle tend to be less fat than cattle not receiving a growth stimulant. Other stimulants appear to give the same quality grade as nontreated animals after the same length of time on feed. Thus, cattle receiving growth stimulants need to be fed to heavier weights to obtain the same carcass grade as cattle not receiving a growth stimulant, with DES-treated cattle being the heaviest.

Table 4. Impact of Growth Stimulants on Performance and Carcass Quality For Animals on Feed the Same Length of Time

		Percent improvement resulting from use of stimulant			
Sex	No. of comparisons	Daily gain	Feed/ gain[a]	Percent change in daily dry intake resulting from use of growth stimulant	Change in carcass quality resulting from use of a growth stimulant
Steers					
DES in finishing rations, oral (Burroughs *et al.*, 1959)	105	13.0	9.5	+2.2	Lower
DES in growing rations, oral (Burroughs *et al.*, 1959)	58	11.8	9.1	+1.6	NR[b]
DES implanted (Burroughs *et al.*, 1959)	35	14.8	10.3	+3.0	Lower
DES (Preston and Willis, 1974)	93	15.0	8.5	NR	Lower
Ralgro (Commercial Solvents Tech. Manual)	35	10.4	6.8	+3.0	No difference
Heifers					
DES in finishing rations (Burroughs *et al.*, 1959)	9	11.7	11.3	-0.9	No difference
DES in growing rations (Burroughs *et al.*, 1959)	12	8.8	6.5	+1.8	NR
DES (Preston and Willis, 1974)	34	11.0	7.0	NR	NR
Ralgro (Commercial Solvents Tech. Manual)	10	6.6	5.9	None	No difference
MGA (Tuco Products Co. Tech. Manual)	21	11.2	7.6	+1.0	No difference
MGA (Preston and Willis, 1974)	21	11.0	8.0	NR	NR

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[a] Improvement in feed/gain as a percent of feed/gain with nonuse of a growth stimulant.

[b] Not reported in tables. However, the authors indicate in the narrative that there was no difference in a majority of the trials.

Our tentative estimates of the shrunk weights at which animals reach low choice (approximately 32% fat in the carcass) when DES, Soynovex-S or MGA are not used are, for steers,

$$\text{(14a)} \quad \begin{matrix}\text{Ch}^{-}\text{ final}\\ \text{weight}\end{matrix} = \begin{matrix}\text{Initial}\\ \text{weight}\end{matrix} + (.885)\left(\begin{matrix}\text{Expected gain to Ch}^{-}\text{ if treated}\\ \text{with DES or Synovex-S}\end{matrix}\right)$$

for heifers,

$$\text{(15a)} \quad \begin{matrix}\text{Ch}^{-}\text{ final}\\ \text{weight}\end{matrix} = \begin{matrix}\text{Initial}\\ \text{weight}\end{matrix} + (.900)\left(\begin{matrix}\text{Expected gain to Ch}^{-}\text{ if treated}\\ \text{with DES or MGA}\end{matrix}\right)$$

Alternatively, if Ralgro is the growth stimulant used, the estimated shrunk weights at which animals reach low choice when a growth stimulant is not used are, for steers,

$$\text{(14b)} \quad \begin{matrix}\text{Ch}^{-}\text{ final}\\ \text{weight}\end{matrix} = \begin{matrix}\text{Initial}\\ \text{weight}\end{matrix} + (.905)\left(\begin{matrix}\text{Expected gain to Ch}^{-}\text{ if treated}\\ \text{with Ralgro}\end{matrix}\right)$$

for heifers,

$$\text{(15b)} \quad \begin{matrix}\text{Ch}^{-}\text{ final}\\ \text{weight}\end{matrix} = \begin{matrix}\text{Initial}\\ \text{weight}\end{matrix} + (.934)\left(\begin{matrix}\text{Expected gain to Ch}^{-}\text{ if treated}\\ \text{with Ralgro}\end{matrix}\right)$$

A detailed literature review of individual studies (particularly direct comparisons across growth stimulants) is needed to test the validity of these estimates and, if necessary, suggest revisions. Research toward this end has been summarized by Embry (1972).

The following partitioning of the impacts of growth stimulants is suggested based upon the experimental comparisons (table 4) of Preston's survey (1975), Madamba's study (1965) of the impact of DES at various slaughter weights and the net energy studies of Fowler _et al_. (1970) and Burroughs _et al_. (1970). The efficiency of energy utilization is taken to be independent of the use of growth stimulants.

Change in Composition of Gain. DES-treated cattle are estimated to deposit 21% more protein and 11% more fat per day than nontreated animals. Energy deposited per pound of gain is reduced, resulting in a 4.6% lower energy requirement per pound of gain. The CNES energy requirements are based upon the use of a growth stimulant. Thus, the net energy requirement for gain of a steer not receiving DES or Synovex-S are similar to those of a treated animal that is 18% heavier. Using Ralgro as a comparison, the requirements for non-treated steers are similar to those of a treated steer that is 12% heavier. For heifers, a 13% adjustment for nontreated animals is used when DES or MGA is used as a reference point; an 8.5% factor is used for Ralgro.

Feed Intake. Research data indicate that absolute feed intake is increased slightly when a growth stimulant is used. However, when the data are adjusted to reflect the fact that treated animals are carried to heavier weights in comparisons where all animals are on feed the same length of time, $DM/W^{.75}$ shows little or no increase.

Feedstuff Nutrient Value Adjustments

Digestive Stimulants

Based upon a review of the literature (Burroughs *et al.*, 1959; Bertrand, 1968; Preston and Willis, 1974) "multipliers" were estimated to adjust for the influence of antibiotics on feed utilization (table 5). The values were estimated by working backward to find the NE_m and NE_g values which would have had to exist in order to generate the daily gains and feed efficiencies reported in feeding trials. The calculations are based upon the assumption that the percentage impacts are equal on NE_m and NE_g.

As new products become available, multipliers to adjust for their impact must be added to the model. For example, calculations suggest that the NE_m^a and NE_g^a multipliers for Rumensin^R fed at the rate of 30 grams per ton of air-dry feed ought to be 1.08 to 1.10, based upon the large numbers of experiments summarized by Elanco (1976), Embry (1976) and Goodrich *et al.* (1976). Garrett (1976b) estimated the ration net energy values of corn and barley diets that included Rumensin, obtaining an NE_g^a multiplier of 1.08. However, no impact on NE_m^a was found.

Our multiplier development strategy begins by using basic research such as Garrett's (1976b) as an apportionment guide for incorporating data from studies where less detailed work was done. However, in the case of Rumensin, if the NE_g^a is adjusted without simultaneously adjusting the NE_m^a, it follows that rations which have a larger component going to maintenance should show smaller improvements in energetic efficiency. The studies summarized by Elanco (1976), however, indicate that the impact of Rumensin on energetic efficiency is probably comparable across rations. Thus, we have tentatively assumed that Rumensin has the same percentage impact on both NE_m^a and NE_g^a.

Table 5. Estimated Impact of Feed Additives on Feedstuff Nutrient Values

	Multiplier	
Feed additive	NE_m^a	NE_m^a
Without Rumensin		
Without growth stimulants		
Without antibiotics	1.000	1.000
With antibiotics	1.040	1.040
With growth stimulant		
Without antibiotics	1.000	1.000
With antibiotics	1.030	1.030
With Rumensin		
Without growth stimulants	1.110	1.110
With growth stimulants	1.100	1.100

Associative Effects (Interactional) on Feedstuff Energy Values

Investigators have long known that the energy values of feedstuffs are influenced by the feeds' proportion in the ration (Swift and French, 1954; Kromann, 1973a,b). But, an important question is, "Are the impacts of the associative effects large enough to require explicit consideration in gain projection and ration formulation models?" Several investigators have examined this question (Lofgreen and Otagaki, 1960; Kromann and Ray, 1967; Asplund and Harris, 1971; Vance et al., 1972; Byers et al., 1975a,b; Lofgreen and Adams, 1975; Gill et al., 1976) and have clearly demonstrated that associative effects are significant. Kromann and Ray (1967), for example, found a 25% reduction in alfalfa hay's NE_{m+g} as it was reduced from 100% to 25% of the ration in an alfalfa-milo diet. Conversely, milo's energy value increased as its percentage in the ration increased. Vance et al. (1972) investigated the impact of varying the proportion of corn silage on the energy values of corn and corn silage. The corn silage NE_g decreased over 50% between the high silage and high grain ration. Byers et al. (1975a,b) observed similar patterns as they varied the diet from 100% corn grain to 100% corn plant forage.

If associative effects are important, the energy values of feedstuffs ought to be higher when fed by themselves than when fed in a mixed ration. For example, a two-phase system where corn silage is fed first followed by an 80 to 90% concentrate finishing ration should be more efficient than a mixed ration that is 40 to 50% concentrate. Dexheimer et al. (1971) and Newland et al. (1975) found that two-phase feeding systems for corn-corn silage rations improved feed conversion by 5 to 10% without materially influencing daily gain. Our simulation work (Fox and Black, 1975) using the model being described, where explicit account is taken of compensatory performance resulting from feeding an all-silage phase prior to feeding a high grain phase as well as associative effects, agrees with the previous studies. Thus, when a wide range of feedstuff combinations is being considered, associative effects must be taken into account in order to obtain accurate gain projections as well as correct economic valuation of feedstuffs.

Application of the present model corresponds well with the work of Goodrich et al. (1974) in which they studied the impact of the level of corn silage in the ration on the performance of steer calves based on research at 17 midwest experiment stations. The Goodrich data were "corrected" for errors in dry matter determination based on procedures implied by Clancy et al. (1975), Fox and Fenderson (1976), Goodrich and Meiske (1971) and Jones and Larsen (1974).

Previous Nutritional Treatment

The nutritional regime an animal has experienced prior to being placed in the feedlot has a substantial impact on the efficiency of energy utilization. On the basis of a review of the literature by Fox (1970) and, particularly, a detailed study by Fox et al. (1972), a continuous multiplier scale ranging from 1 to 9 was devised based upon body composition and previous rate of gain at the time the animal was placed on feed. Typical values are depicted in table 6. The NE_m multiplier differs from that of the NE_g. While the biological basis for this is not clearly understood, possible explanations are discussed by Fox (1970).

Table 6. Estimated Impact of Previous Nutritional Treatment on Feedstuff Nutrient Values

Scale value	Body condition	Previous rate of gain, lb./day[a]	Multiplier	
			NE_m^a	NE_g^a
1	Very fleshy	2.3	0.955	0.90
2	Average	1.5	1.000	1.00
9	Very thin	.7	1.045	1.10

[a] Based upon an average frame steer calf.

Daily Dry Matter Intake

The dry matter intake component must be consistent with the energetic components of the model for accuracy in gain and feed conversion projection. Dry matter intake is influenced by a wide set of factors including age, weight frame size, breed, energy density of the ration, physical form and degree of fermentation (Balch and Campling, 1962; Baumgardt, 1969; Church, 1971; Jones, 1972; Simpfendorfer, 1974; Ayala, 1974).

Daily dry matter intake is assumed to be limited by high fiber content in rations; but, as rations become less fibrous, fiber no longer restricts intake. As the energy density increases further, a point is reached (probably between 60 and 70% corn in corn-corn silage rations, DM basis) at which chemostatic and themostatic controls take over. Daily energy intake and gain are approximately constant, while daily dry matter intake falls as the energy density is increased. Beyond approximately 90% concentrate, daily gain is depressed and daily dry matter intake falls even faster.

Our basic dry matter intake equation is

$$\text{DMI} = \begin{cases} (.100)(\text{BREED})(\text{AGE})(W_{kg}{}^{.75}) & \text{for equivalent weights less than 800 lb.} \\ (.095)(\text{BREED})(\text{AGE})(W_{kg}{}^{.75}) & \text{for an equivalent weight of 950 lb.} \\ (.090)(\text{BREED})(\text{AGE})(W_{kg}{}^{.75}) & \text{for an equivalent weight of 1050 lb.} \\ (.090)(\text{BREED})(\text{AGE})(\text{Weight equivalent to 1050})_{kg}{}^{.75} & \text{for equivalent weights greater than 1050 lb.} \end{cases}$$

where DMI is daily dry matter intake, kg, and W_{kg} is empty body weight, kg, for energy densities between where intake is limited by neither the fibrousity nor the energy concentration of the diet. The breed and age multipliers are given in table 7.

Table 7. Estimated Impact of Various Factors on Daily Dry Matter Intake

Item	Multiplier
Age	
Started on feed as calf	1.00
Started on feed as yearling	1.10
Started on feed as 2-year-old	1.15
Breed	
British	1.00
Exotic	1.00
British x exotic	1.00
Holstein	1.17
Holstein x British	1.09
Feed additives[a]	
Without Rumensin	
Without growth stimulant	
Without antibiotic	1.00
With antibiotic	1.00
With growth stimulant	
Without antibiotic	1.00
With antibiotic	1.00
With Rumensin	
Without growth stimulant	.91
With growth stimulant	.91

[a] The assumptions refer to feedlot rations. Antibiotics have shown an impact on intake in some backgrounding rations for calves.

Under conditions where energy concentration limits intake, the following equation holds:

$$NE_g^r = (.05272\bar{G} + .00684\bar{G}^2)(WE^{.75})/(BREED)$$

where $\bar{G}$ = maximum gain, $FFG = NE_g^r/NE_g^a$, $FFM = NE_m^r/NE_m^a$ and $DMI = FFM + FFG$. Thus, dry matter intake for a .63 NE_g ration is approximately 90 to 92% of that for a .57 NE_g ration. Garrett (1975), Brokken _et al_. (1976) and Carlson (1976) have worked explicitly on integrating the impact of energy density of the ration into gain projection work.

Daily dry matter intake is not adjusted upward for cattle placed on feed in "thin" condition. They may eat more when first placed in the feedlot, but intake over the entire finishing period does not appear to differ from that of cattle whose growth was not retarded (Fox, 1970). Analysis of the finishing phase of Oregon experiments (Ralston et al., 1971) where steer calves had been fed backgrounding rations which gave daily gains ranging from .03 to 2.4 lb. per day gave similar results.

The daily dry matter intake component of the model is a "first cut." On the average, it conforms well with data examined to date, particularly for cattle started on feed as calves. However, work is needed to investigate the impact of initial age:weight ratios (after appropriate adjustments for frame size) and to examine, in detail, the structure of intake over the feeding period. The current component may be in error for weights in excess of low choices; intake probably declines once animals reach low choice rather than just plateauing. Too, examination of yearling data from Oregon suggest that intake per unit of metabolic weight may be higher than we have suggested early in the feeding period but drops more rapidly. Current investigations focus on examining detailed period records for cattle of alternative frame sizes, breeds and initial ages and fed rations ranging from high corn silage to high corn grain.

Carcass Quality and Yield Grade Projection

Carcass quality and yield grades measure attributes which are used in the prediction of eating qualities and, ultimately, retail demand. Too, the amount of fat which will be trimmed is related to the percent fat in the carcass (Fox and Black, 1975). Analysts routinely calculate the estimated differences in dollar value among carcasses of various yield grades.

Few data allow direct estimation of quality and yield grades on the basis of empty body weight. Estimates are available (table 1) for empty body fat at a given empty body weight. Carcass fat can be estimated from empty body fat (e.g., Garrett and Hinman, 1969) and yield and quality grade can be estimated from carcass fat. Table 8 gives our estimates of the quality and yield grades associated with percentages of fat in the carcass. They are based on studies in which carcass characteristics and chemical composition were obtained from cattle slaughtered at various stages of growth (Madamba, 1965; Lofgreen and Garrett, 1968; Riley, 1969; Dockerty et al., 1972; Ayala, 1974; Simpfendorfer, 1974).

The yield grade estimates are probably more accurate than those for quality grade. Yield grades are directly related to percent fat in the carcass. Quality grade, in addition, is a function of marbling score which is subject to variation in the distribution of fat within the carcass.

Applications

The framework described herein is a useful standard of comparison and provides a powerful format for summarizing our present knowledge of the factors influencing the performance of growing and finishing cattle. As such, it provides a computational framework which may be used in working with cattle feeders to assess the efficacy of the many alternative cattle feeding strategies and management systems available. Furthermore, the use of a sound, systematic approach to cattle feeding experimentation is an important research tool which can alert us to areas which require further investigation and to suggest promising areas of new research which will ultimately benefit the cattle feeder.

Table 8. Estimated Carcass Quality and Yield Grades

Empty body, % fat	Carcass, % fat[a]	Quality grade[b]	Yield grade[c]
25.6	28.5	Gd+	2.2
26.9	29.8	Gd+	2.5
28.1	31.2	Gd+	2.8
29.3	32.5	Ch-	3.1
30.6	33.8	≥Ch-	3.4
31.8	35.2	≥Ch-	3.7
33.0	36.5	≥Ch-	4.0
34.2	37.8	≥Ch-	4.3

[a] The estimated relationship between percent fat in the carcass (CF) and percent fat in the empty body (EBF) is $CF = .7 + 1.0815\ EBF$; $R^2 = .98$ and $\hat{\sigma} = .5$ (Garrett and Hinman, 1969).

[b] The relationship between the percent fat in the carcass and quality grade (QG) was estimated from data assembled by Crickenberger et al. (1976), Madamba (1965) and Riley (1969). The estimated relationship is $QG = 2.5 + .23CF$ for $38 \geq CF \geq 15$ where Gd^o is 8; Gd+ is 9; Ch- is 10 ... The equation represents an average of the studies. The proportion of the variation in QG associated with CF ranged from 62 to 72%; parameters were significant at $P>.01$. There was no evidence of nonlinearity over the range studied. Breeds included Angus, Hereford, Angus x Charolais and Angus x Hereford. Breed differences were significant ($P>.01$), with Angus requiring less fat to reach a particular grade.

[c] Estimated yield grade based upon data of Crickenberger et al. (1976) is $YG = -1.7 + .15CF$ for $40 \geq CF \geq 25$ and of Riley (1969) $RY = 86.35 - .6662CF$ for $42 \geq CF \geq 13$; $R^2 = .84$; $\hat{\sigma} = 2.2$; $n = 121$ where RY is retail yield. The estimates are significant at $P>.01$. Preliminary statistical analyses of the Crickenberger et al. (1976) data suggest breed differences in the relationship, at least in the intercept, when cattle of Holstein breeding are included.

Typical uses include development of extension publications for use by cattle feeders and industry personnel, ration evaluation and formulation and performance simulation for individual cattle feeders; determination of the best feeding system from a whole farm perspective; and applied research in energetic and economic areas (e.g., Black and Fox 1975). The acceptance of these models by medium and larger sized cattle feeders has been encouraging. This role is expected to become even more important in the future as cattle feeding operations become larger and as new information allows improved accuracy of predictions. A previous paper (Black and Fox, 1976) describes the field application of these models.

Conclusions

This paper has described a generalization of the California Net Energy System. While many parameter values will be altered as knowledge becomes more complete, our objective has been to develop a framework which permits values to be updated as new information becomes available and as new technological breakthroughs are attained. Extensive experimental and field testing is necessary under South Dakota conditions. However, the generalizations and associated "multipliers" appear reasonable for most situations. It is hoped other investigators will use this or a similar system to routinely check the accuracy of performance projections against experimental and farm trials and suggest revisions when warranted.

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