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To the Graduate Council:

I am submitting herewith a thesis written by Martin Raber Ehlers entitled "Formulas for determining total net energy in multiphase feeding regimes." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Science.

James A. Corrick, Major Professor

We have read this thesis and recommend its acceptance:

J. W. Holloway, J. D. Smalling

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

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J. W. Holloway

John D. Smalling

Accepted for the Council:

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Graduate Studies and Research

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FORMULAS FOR DETERMINING TOTAL NET ENERGY IN MULTIPHASE FEEDING REGIMES

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Martin Raber Ehlers

August 1978

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ABSTRACT

Retrospective analysis of studies carried out at he University of Tennessee between 1967 and 1971 were employed in the development of formulas for determining the projected total net energy for maintenance and gain in multiphase treatment regimes. Methods were applied to these formulas in order to yield a practical application whereby the total projected consumption of any beef animal could be obtained.

The data from three studies was subjected to the formulas for net energy for maintenance and gain which yielded the net energy required on any day. Mathematical procedures were applied which yielded equations for calculation of total net energy in two phase treatment regimes over the total treatment time in a discontinuous fashion. These equations, which must be worked the number of times as there were days in a phase for both maintenance and gain, were replaced with one equation each for net energy for maintenance and net energy for gain in each phase through the use of integration procedures. The net energy required, as calculated by this method, was then divided by the net energy for maintenance and gain provided by the multi-component ration, as calculated by using weighted percent or associative formulas. The result of this manipulation was a calculated, projected figure for total consumption. Replacing the variables in the formulas derived by integration with the data from the past studies yielded a projected total consumption which could be compared with the original, observed consumption.

Statistical analysis of the projected consumption versus the observed consumption in these three studies indicate that this method has a high potential for calculating the amount of feed necessary for projected single or multiphase feeding programs.

FOREWARD

Due to the retrospective nature of this thesis some explanation of its presentation became necessary. Methods were employed in the application of new theory to old data which for reasons of continuity, require brief enumeration.

The study to follow was based on other studies carried out at The University of Tennessee between 1967 and 1971; predominantly a two phase urea-limestone corn silage/ground shelled corn study labeled H-72-KB-3. The literature search of this thesis investigated these aspects, as well as the literature on various forms of metabolic energy with which the body of the thesis was primarily concerned.

The author devised a method to utilize the ration and gain data from these earlier studies to check and test a formula he derived concerning the metabolic requirements of beef cattle in multi-phase, silage/grain, feeding regimes. By fitting the appropriate mathematical procedures it was possible to determine and test a number of formulas without actually having to perform a field study. The determinations and tests included deriving a formula for the total net energy required by any beef animal over any time and at any rate of gain with any number of phases; the net energy provided by the ration, derived and tested through two different methods; and the comparison of actual intake of a ration as obtained from the original studies with the intake as estimated by the use of said new net energy formulation.

It is difficult to fit new material to previously set data since one is limited in the variables he can explore and utilize. This thesis, therefore, required extended periods of time, ingenuity and error before suitable application and checks were successful.

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CHAPTER I

LITERATURE SEARCH

Levels of Feeding

Concentrate to Roughage Ratios. Several experimenters have explored the ratio of concentrate to roughage in order to determine the most efficient production short of phase systems. Keith et al. (1952) explored concentrate to hay ratios of 4:1, 3:1, 2:1, and 1:1, 1:3 respectively. The best average daily gain (ADG) was 2.09 lb. at 2:1 concentrate to hay while the ratios of 2:1, 1:1, and 1:2 were, as a group, the most desirable for normal function of digestive systems, ADG and feed efficiency. Stanley (1953) employing rations of 2:1 and 1:3 concentrate to hay inclusive, obtained similar results.

A ration regime of 1:1, 1:3, 1:5 roughage to concentrate was explored by Richardson et al. (1961). He reports improved ADG at 1:5 (2.27 lb. versus 1.97 lb.) and carcass data for the 1:3 and 1:5 ratios. Richardson, Smith and Cox (1953) used these very rations and verify the results.

Both Connell et al. (1954) and Dowe et al. (1951) using very wide concentrate to hay ratios found that in terms of ADG, 3:1 and 2:1 were equally good. Using alfalfa-brome soilage with various levels of corn ranging from 20:1 to 2:1, Woods and School (1962) found linear increases in ADG (1.34 lb. to 2.66 lb.) with the additions of corn. The all forage rations needed 88 days more feeding time. They note it took 8.9 lb. forage to replace 1 lb. of corn and, therefore, only at these ratios of cost should forage replace concentrate.

Employing different percents of ground shelled corn (GSC) to hay (65:25, 55:35, 45:45) Cmarik et al. (1957) observed that ADG, lb. total digestible nutrients (TDN)/c lb. gain, and grade showed little difference between rations. They conclude that roughage can make up a relatively high percent of a fattening ration. Pope et al. (1957) fed concentrate to roughage ratios of 35:65, 50:50, 65:35 and 80:20 to a constant finish grade. These results also showed the least concentrate ration as good as the high concentrate in terms of ADG while feed costs were lower and time to slaughter not different for the higher roughage ration.

Feeding high energy versus high roughage rations of corn and up to 30% hay Anthony et al. (1960) and (1961) concluded that mixtures containing 30% hay was equal to the more high-grain mixture for fattening calves to slaughter finish. He stated further that more "reach" lies in developing high roughage rations.

La Verne Bucy and Bennion (1962) employed high concentrate to roughage ratios of 85% and 100% and found that the lower concentrate group gained better and graded equivalently. In two feeding trials Parrott et al. (1968) fed ratios from 100% hay to 100% steam processed milo in 10% increments. The results indicate that digestible energy (DE) and dry matter (DM) intakes were reduced above the 60% concentrate levels suggesting a reason for decreased performance at very high percent concentrate rations.

Ralston et al. (1966) used three close energy levels (69, 72, and 78%) with three levels of protein to see if any statistical difference in ADG and carcass data would result. In all combinations at such small variance no statistical differences ($P<.05$) were obtained. However, the medium protein, high energy ration gave slightly improved ADG.

Corn Silage as a Finishing Ration. Tomhave (1920) reported on a study in which a full grain ration was compared with a two-thirds grain ration and corn silage. The ration with corn silage (CS) had about the same ADG and carcass value while the cost to produce 100 lb. of gain was lower. In a number of tests from 1912 to 1915 CS and hay was compared to CS alone, both being supplemented with corn. Again, in all tests net returns favored the greater amount of CS. In a massive study from 1915 to 1919, 190 Pennsylvania farmers cooperated in a feeding study with 3,000 cattle. The rations were unlimited CS with limited grain versus full grain feed. Because of small differences in ADG (2.1 lb. versus 1.8 lb.) and days on feed (222 versus 233) the rations with corn silage returned significantly ($P<.05$) more to the farmer ($15.01 versus $31.76). Pinney (1966) fed steers GSC at 1.5, 1.0 and 0.5% body weight and CS ad libitum for 125 days. He also reports no significant difference in ADG and carcass grade with increased CS, as well as better economy of gain.

Klosterman et al.(1959) fed rations of either GEC full fed or one-half GEC and CS. The steers on one-half GEC with CS full fed gained 0.20 lbs. per day faster than the GEC full fed group. He also postulated that the estimated net energy of CS when fed in this manner may be fully equal to GEC alone.

Rations utilizing high and low moisture grain silages alone and with GEC or with corn silage: plain CS with cottonseed meal (CSM) and high grain rations were compared by Hammes et al. (1964). He reports that grass silages alone were poor except when supplemented with 8 lb./day of GEC. CS at 80 or 100% were not significantly ($P<.05$) different from high grain rations in terms of ADG and grade while showing the best feed efficiency.

Corrick and Hobbs (1968) fed diets comparing untreated CS and concentrate, urea/lime treated CS, GSC and alfalfa hay. Again the ration containing high CS, expecially the urea/limestone silages, proved most economical.

Newland and Henderson (1966) proposed a special high energy corn silage (only ears from alternate rows) and compared it with regular CS, both supplemented with 4 levels of concentrate. When all levels were pooled the high energy corn silage was significantly ($P<.05$) better than regular corn silage (1.30kg versus 1.13 kg ADG). In a second experiment, again utilizing high energy corn silage versus regular corn silage but utilizing a protein supplement, the high energy corn silage was again better in terms of ADG and carcass grade. They estimated the high energy corn silage is equivalent to regular corn silage plus one-half to three-quarters percent body weight in daily added concentrates.

Phase Feeding

Two Way Phase Systems. Several researchers have compared high and low energy rations utilizing a simple two way system. Miller et al. (1967) compared rations of approximately 91% ground corn and 9% alfalfa hay with a ration of 74% hay and 26% ground corn. He further compared both with a phase system by feeding the latter to 340 kg (from 177 kg) and the former to 454 kg. The ADG obtained was 1.16, 1.07 and 1.28 kg respectively and feed per 100 lb. of gain was 701, 798, and 751 kg. These results were statistically ($P < .05$) different in both parameters for the two phase system. Further, the high energy and phase system scored equally in dressing percent and carcass grade. A similar system was used by Hendrickson et al. (1965) but he expanded the two phase system to include an inversionary high and low energy phase. That is to say, he compared medium energy for 200 lb. of 400 lb. and switched to high energy for the last 200 lb. while in another ration he began high energy and switched to medium at corresponding weights. These were tested also against full term high energy and full term medium energy rations. The full term high energy ration resulted in better feed efficiency and carcass grade than the full term medium energy ration. The phase system of medium/high yielded results essentially the same as the full term high energy while high/medium phase gave results similar to the full term medium energy ration. He concluded fat development during the second 200 lb. gain was important in carcass quality and overall efficiency in finishing cattle. Klosterman _et al_. (1965) using this same inversion of phase with CS versus ground ear corn obtained very different results. He concluded that there was no difference whether corn was fed the first or last half or in the middle of the feeding period.

McCampbell (1921) fed alfalfa hay and two lb. CSM _ad libitum_ corn and cane silage versus the same ration but with the corn witheld for the first 120 days. In terms of economics the witholding of corn resulted in $4.00/head profit increase. In terms of return per acre the astounding differences were $120/acre of silage versus $48.00 per acre of corn. This indicated that the less corn fed without damaging other variables, the more return to the farmer on a per acre income basis. However, this same experiment was done at a later date when the price of feed was much lower. The silage group returned $5.00 less per head while still returning more per acre ($72.00 versus $22.50).

Both Hale et al. (1962) and Tomhave (1920) fed typical full fed CS rations with soybean meal (SBM) and compared it with that same ration supplemented with either hominy or corn for approximately the last 90 days of a 130 day feeding system. They both conclude such phase supplementation was unnecessary since while all other parameters remain the same the CS ration costs less per lb. of gain.

Multiphase Systems. Adjusting the amount of concentrate in the ration over time as a percent body weight or by predetermined amounts leads to a feeding system which is complicated but hopefully the most efficient. Many researchers have experimented with this type of multiphase ration.

Young et al. (1962) adjusted a CS alfalfa hay basal ration with ground shelled corn at 14 day intervals according to body weight. He compared this with a two phase system where corn was full fed until after the first 98 days of a 184 trial. In terms of total gain, feed efficiency and carcass quality he concluded that both methods could be used to produce similar choice yearling heifers. Kolari et al. (1963) used essentially the same two feeding regimes and two others of ground ear corn full fed and ear corn with silage to test ways of feeding. He also concluded the two phase and numtiphase systems and full term systems had little effect on ADG and carcass grade. Richardson et al. (1961) compared a 28 day changing ration with 1:1, 1:3, and 1:5

roughage to concentrate rations. The phase system was somewhat more effective in ADG and carcass quality than the 1:3 and 1:5 full fed rations.

Using concentrate and roughage feeds Johnson et al. (1958) tested a multiphase ration. The basic ration was corn and roughage mix for 168 days. In five others the corn was witheld for the first 28, 56, 84, 112, and 140 days with the basal corn and roughage mix for the remainder of each feeding period. Cattle on the last three rations above gained significantly ($P<.05$) slower but yielded savings in feed costs (no corn for 140 days = 49.2% cheaper than basal).

In a basic CS ration Neumann et al. (1963) added cracked corn for the entire feeding period as well as for all but the first 126, 189, and 250 days. Steers per acre of corn (yield 20 tons CS or 100 bu. corn) was 2.0, 2.2, 2.1, and 2.9 respectively. The pounds of finished steer per acre were 1042, 1190, 1103, and 1494 while carcass grade and value remained constant. These results further indicate that corn can be added at a later time in finishing while resulting in the same carcass value but more beef per acre. This gain, however, must be sufficient to affect the loss in feeding time to grade, (full fed 214 days versus delay for 250 days at 195 days to grade).

Effects of Energy Level on Ration Constituents

Effects on Ration Protein. Lofgreen et al. (1963)

employed four different rations. Low energy-high protein, high energy-low protein, low energy-low protein, high energy-high protein, in a nitrogen balance trial with dairy calves. The effect of energy on nitrogen retention was dramatic with energy level. Calves on a low protein diet showed a 20% increase in nitrogen retention (as percent of apparently digested nitrogen above maintenance needs) when given a high energy versus a low energy diet. Animals on a high protein diet did not show the same results as excess protein was probably used for energy. Using 8, 10 and 12% protein levels with various amounts of crerlose Fontenot et al. (1955) got opposing results. He noted that added cerelose with low percent protein pushed nitrogen retention down while it enhanced nitrogen retention at higher levels of protein. Stone and Fontenot (1965) however, indicated that changing available energy while keeping protein constant at 12.5% did not have any effect on nitrogen retention. Baird et al. (1967) found that the digestibility of protein was significantly ($P<.05$) lowered when the grain in the ration was increased from zero to 75% at 25% intervals.

Arias et al. (1951) used six different sources of energy (dextrose, maltose, sucrose, starch, cellulose and GEC) at three different levels with a constant amount of urea protein. The results show that each energy source aided urea digestion. Using fat and urea to adjust the protein and energy of rations Jones et al. (1961) found that nitrogen retention was not affected by energy level.

Effects of Energy Level on Ration Components. Parrott et al. (1968) utilized rations of milo and alfalfa hay containing from 100% roughage to 100% concentrate to test the digestion of cellulose as the grain level increased. Below 40% grain there was little effect on cellulose digestion. However, above 50% grain, cellulose digestibility decreased as the amount of grain increased. Feeding 62, 67, and 72% energy as TDN Stone and Fontenot (1965) observed also the reduction in crude fiber digestion as the energy level was increased. The crude protein (CP) and ether extract (EE) were not influenced by energy concentration but the digestibilities of DM, organic matter (OM), and nitrogen free extract (NFE) were increased with increased energy concentration.

Arias et al. (1951) stated that the results of an experiment involving six sources of energy and three levels indicated that carbohydrate aided cellulose digestion. Feeding rations with roughage to concentrate ratios of 1:1 to 1:5. Dowe et al. (1955) indicated also that there may be a limit to the amount of energy in a ratia that will improve cellulose digestion by noting that 1:3 was best. He also reported that the digestibility of DM and EE were up as corn was up while NFW, crude fiber (CF) and protein were similar for all rations.

Elam et al. (1958) fed three different energy levels (full fed, two-thirds full fed and maintenance). Degestibility of OM, NFE, and energy was higher for the two-thirds.

ration over the high or low energy lots. Average digestibility of EE, CP, or CF were lower for high energy lots.

Urea Feeding

Urea and the Ruminant. By 1946 considerable interest had been shown in use of non protein nitrogen (NPN) for feeding ruminants. Briggs et al. (1947) state:

> During the current shortage of protein concentrates, considerable interest has been shown in the possibility of replacing a part of the protein of livestock rations with other forms of nitrogen. This possibility has never been realized to its fullest extent. Urea, $CO(NH_2)_2$, contains 46.6 percent nitrogen, one pound of urea furnishing as much nitrogen as 6.77 pounds of 43 percent protein cottonseed meal.

Chemical and bacteriological studies of rumen processes demonstrate the formation of protein from NPN though the intervention of microorganisms inhabiting the rumen. Bulletin 409 (1953) of the Oklahoma agriculture experiment station qualified this statement.

> Bacterial synthesis of protein from urea proceeds in two major steps: (1) the urea is broken down to ammonia, and (2) the ammonia is then combined with carbohydrate fragments to form protein in the bacterial cells.
>
> The second step must keep pace with the first one to prevent the accumulation of ammonia; thus rapid growth and multiplication of the rumen bacteria are necessary. Rapid growth of bacteria can best be assured by providing in the ration: (a) readily-available carbohydrate (energy) contained in cereal grains and molasses; (b) a relatively low level of natural protein supplements, and (c) minerals.
>
> Production of ammonia in excess of the immediate needs of the bacteria is a waste of nitrogen and

may be detrimental to the animal if the excess is great. Dosing with urea, or allowing animals to consume large amounts over a short period of time, may lead to diastrous resuts.

By feeding urea only as recommended below, excess ammonia production can be avoided.

Of all the NPN compounds; urea, biuret, amides, amoniated agricultural products and common ammonium salts only urea has been thoroughly tested. Still, there lingers considerable question on the fine points of urea feeding and metabolism which are best summarized by Gallup (1956). He stated that in the use of urea

> The essence of the problem as it appears to the chemist is this: to prepare a nitrogen compound that can compete with vegetable proteins in ruminant rations, with full consideration being given to the cost of such a product, its stability and handling and mixing properties, its palatability, solubility, and possible toxicity, and its ability to liberate in the rumen metabolizable nitrogen at a rate commensurate with the requirement of rumen organisms.

Urea Fed with and in Corn Silage Rations. Urea has been and still is being fed in corn silage (CS) rations being added either at the time of feeding or ensiling. NPN is tested as a protein source by coparison with natural plant protein usually in terms of gain, efficiency of gain and carcass quality. Primarily urea is tested against soybean (SB) protein.

An experiment by Pope (1959) is indicative of those done by adding urea at the time of feeding. Using a milo supplemented CS ration; thirteen supplements, including urea, were compared to SBM on a protein equal basis. Although urea resulted in lower gains, feed efficiency and carcass grade, these were not statistically significant ($P<.01$). In a similar test, however, Stenberg and Tolman (1968) found a difference in ADG ($P<.10$) between urea and SBM supplemented CS rations.

Tolman and Woods (1966) added either urea or SBM or two-thirds SBM one-third urea, or vice versa to a CS ration at the time of feeding. Examining the respective ADG for the above four treatments (0.69, 0.76, 0.72, 0.71 kg) he concluded that urea was a good supplement when fed alone or with SBM in a CS ration. Baker et al. (1949) carried out a similar experiment comparing urea and steamed bone meal; steamed bone meal and soybean oil meal, and soybean oil meal alone. He concluded these three supplements resulted in little apparent difference in ADG, finish and appearance.

Researchers have also studies the additin of urea to corn silage rations at the time of ensiling. This method also is compared with natural protein in terms of feeding value.

Stenberg and Tolman (1968) set up an experiemtn whereby he compared the supplementing of urea at feeding time, urea ensiled, and SBM at feeding time. He concluded that ensiled urea was equal to urea added at time of feeding (ADG - 0.69 kg versus 0.71 kg respectively) and that SBM was superior to both at 0.77 kg ADG. Bently et al. (1955) compared CS plus corn and urea, CS plus corn and SBM at time of feeding with urea corn silage and corn and urea phosphorous corn silage and corn. His results in terms of ADG and cost per hundredweight were: 1.77, 1.87, 1.82, 1.83 lb./day and 13.82, 13.98, 13.05 and 12.89 dollars per hundred weight respectively. The obvious conclusion was that urea silage compared favorably with CS and SBM.

The use of 0.5% urea and 0.5% high calcium limestone in supplementing CS at time of ensiling has emerged as an acceptable level of supplementaion. Silage treated in this manner was compared to silage which was not so treated by Klosterman _et al_. (1961). Both silages were fed with SBM, alfalfa hay and grown ear corn for 224 days. He discovered the heifers on treated silage gained significantly ($P<.05$) faster and required less feed/cost gain. Klosterman _et al_. (1962) noted that the addition of urea in making CS improved its feeding value as well as replacing a large part of the protein supplement needed in a CS ration.

Ruminant and Ration Energy

Objections to Total Digestible Nutrients. Throughout a period of the last two decades there have been a number of researchers realizing what they believe to be the shortcomings and inaccuracies of total digestible nutrients (TDN) as a measure of the potential nutrient value of feeds. Simultaneously, there has evolved the realization that the value of a feed may be expressed in terms of dietary energy: as digestible energy (DE), metabolizable energy (ME) and net energy (NE). Blaxter (1956) says of TDN:

> It measures what food contains, rather than what animal performance it can promote. Its advocates are impressed by its simplicity and infer that it is a more accurate measurement than systems based on the net energy principle. This inference may appear true in that the errors of measuring TDN are small compared with those of measuring net energy, but the inference is really false in that the aim of any system of evaluation is to predict animal performance with maximal accuracy, not to measure what food contains.

The desirability of adopting DE in the place of TDN has been explored by several individuals. Mitchell (1942) pointed out the inherent errors in the use of TDN as a measure of food energy, saying

> The metabolizable energy is a more significant measure of the value of a feed or ration in satisfying the energy requirements of the animal than is the sum of the total digestible nutrients, because it excludes wastage of energy for which no reduction is made in the mere estimation on nutritive material of the food that does not reappear in the feces.

Swift (1957) indicated that determination of energy values by the bomb calorimeter is one of the most accurate analyses performed in the laboratory while serving the same purpose as TDN without TDN's "Laborious, cumbersome, and inaccurate" characteristics. He further indicated that the only problem is salvaging the TDN values accumulated over the years. In a study combining the determinations of TDN and DE from 312 trials, he concluded that one pound of TDN = 2,000 calories of DE. Lofgreen (1951) points out that using the TDN system all protein and carbohydrates in all feeds are equal in value and further, that all fats have an energy value 2.25 times that of protein or barbohydrate. As an alternative he suggests an energy method utilizing the bomb calorimeter. In this method it is necessary to determine moisture, ash and heat of combustion on feeds and feces in a digestion trial and ether extract in the feeds, thus avoiding the complete proximate analysis. In comparing the two systems he found no significant differences in results while there was a great saving in time obtained by calculating TDN from DE.

Development and Use of the Net Energy System. By 1960 several researchers were seriously considering the energy system. Pioneers in the development of the use of energy were Otagaki and Lofgreen (1960) who said, "It cannot logically be disputed that NE is theoretically to be preferred as a measure of useful feed energy over such measures as TDN, DE and ME." He began developing the NE concept by feeding the ration in question at two levels and determining the energy gain brought about by the feed increment (difference trial). His mathematical model was:

$$NE_i = G_2 - G_1$$

where NE_i is the NE of feed increment per unit metabolic size and G_2 and G_1 are energy gain per unit metabolic size.

Kleiber (1961) was one of the first to realize that partial effect of energy utilization for maintenance is higher than it is for production. Lofgreen (1963) also realized from other research that the NE per unit of feed was higher from zero to sub-maximum than from sub-maximum to maximum. This being the case, it became necessary to know the NE of the feed increment for production alone and for maintenance and production. Thus, the term $NE_{m\&p}$ as defined by Harris (1963):

> When reporting NE, it should be clearly stated which fractions are included. For example, there may be values for NE for maintenance plus production ($NE_{m\&p}$), or NE for maintenance only (NEm), or NE for production only (NEp). The subscripts are suggested because there is often confusion. . .

became predominant in the work of Lofgreen and other authors. Lofgreen (1963) tested this equation in a comparative slaughter trial with yearling heifers comparing alfalfa hay to a concentrate mix. The results showed a marked decline in $NE_{m\&p}$ for both rations as feeding level increased. The results also indicated that the partial net energy of a feed used for weight gain does not deviate significantly from linearity from maintenance to ad libitum feed consumption. This suggested, according to the author, that the partial net energy of feeds for maintenance and gain was more nearly consistent than the total $NE_{m\&p}$. The NEm for alfalfa was 67% that of the high concentrate while alfalfa NEp was only 49% that of the high concentrate.

In a trial by Hall et al. (1968) the NE values of corn versus sorghum grain were determined when fed at three different levels. He found that neither grain or level of feed above maintenance affected NEp values, which supports the idea that the partial efficiencies of feeds at levels above maintenance are rectilinear or that succeeding increments of feed above maintenance have a constant NEp. Garrett et al. (1964) also confirmed the idea of constant NEp. Vance et al. (1972) found ration NEm values increased linearly in various corn/corn silage rations, indicating the NEm of each feed was also constant. He does, however, disagree with other researchers on the linearity of NEg. The NEg content of each feed ingredient was not constant but depended on the composition of the ration as a whole, particularly when high levels of concentrate (85-97%) were fed. Kromann (1967) also espouses the idea of associative effects of complex rations and reports on a method for determining the caloric value of ration ingredients. His equation involved the simultaneous solving for Xj (NEm&p of food components) of n different components in n different rations. He used this method to test the idea that the energy value of the basal ration remained constant with the addition of molasses at 10, 25, and 40%. His results differ from other researchers as he found that the DE value of the basal ration decreased as molasses in the ration increased. The NEm&p of alfalfa hay decreased as milo was added to the ration; also, the NEm&p of milo decreased as alfalfa was added to the ration, all indicating the associative effects on ration component net energy evaluation.

Preston (1975) studied the addition of corn silage to a concentrate ration in terms of NE. The NEm&g decreased with the addition of corn silage but, as with most investigators, the NEg values of individual feeds are additive and not dependent on relative proportions of grain and silage. Byers, Matsushima and Johnson (1974) however, are of the opinion that the associative effects of feeds occur whenever feed ingredients are mixed together; especially grains and roughages. With this in mind they set up equations for predicting the net energy values for maintenance and gain of mixed corn grain/silage diets using regression

$$NEm = 6.449 \cdot 10^{-7} (\%\text{total corn})^3 + 1.72$$

$$NEg = 8.491 \cdot 10^{-5} (\%\text{total corn})^2 + 1.24$$

in order to provide a practical means of assessing the expected NE value of mixed diets. This system is not subgect to the limitations of the California net energy system as the precision of prediction is not decreased as the limits of feed interaction approach the independent energy value of the primary feed ingredient.

Lofgreen and Garrett (1968) have written the most definitive article to date on the theory and use of the net energy system. Several in use concepts and equations deserve reiteration here. At zero feed intake heat increment is zero and heat production is therefore basal metabolism and heat of activity which is equal to the NEm. By extrapolating HP at various levels of feeding on metabolizable energy intake in comparitive slaughter trials they have developed an equation for calculating NEm for any size cattle

$$NEm = 0.077\ W^{0.75}$$

where NEm is in Mcal./day and W is body weight in kg. In order to determine if sex was a factor in NEm requirements they tested steers and heifers in comparitive slaughter trials. They concluded that the heat produced by fasting steers and heifers is not different, and the NEm for both is as previously indicated.

In similar experiments they determined that energy concentration in the weight gain increases as the rate of gain increased and that increase is more rapid in heifers. This is supported in a study by Klosterman and Ockerman (1968). The results of which indicated a ration X sex interaction giving heifers a NE value for corn silage greater than steers. This led to the development of two further equations by which the energy stored in weight gain, or the NEg requirements, can be expressed as

$$NEg = (52.72g + 6.84g^2) \cdot (W^{0.75}) \qquad \text{(Steers)}$$

$$NEg = (56.03g + 12.65g^2) \cdot (W^{0.75}) \qquad \text{(Heifers)}$$

where NEg is in kcal, g is daily gain in kg and W is body weight in kg.

By the development of these three equations it became possible to calculate the requirements at any weight and for any rate of gain.

The "Grain of Salt" Clause for NE Systems. There still exists a great deal of controversy concerning the ability of NE to predict the ability of a food to sustain a particular level of animal production. Blaxter (1956) insisted nutritive value is a biological measurement caught up in the reticulate nature of life at the orgasmic level. He believed science does not know enough about the thermodynamics of intermediary metabolism to enable us to predict from the chemical composition of a food its ability to act as a free-energy supply in the body. He wrote of "intrinsic net efficiency" of foods indicating that measures of NE are only as good as the animals used and the type of physical function they support. He pondered the still not answered question of rectilinear or curvilinear response of food at different levels of feeding, therefore questioning the consistency of nutritive value at higher rates of gain. The supply of other essential nutrients, like protein, certainly affect the nutrient values of a feed expressed as energy. Perhaps Blaxter (1956) summed up these queries on nutritive value of a feed evaluated by any method:

> The above discussion makes it clear that the problem of predicting the ability of a food to sustain a particular level of animal production is by no means an easy task. The nutritive value of a food is not a constant; it vaires signigicantly with the species considered, the type of production it supports, the amount of it which is given, its physical state, and the ration to which it is added.

It appears that many of the problems in ration evaluation with respect to the NE system have been scientifically resolved to a reasonably acceptable level. We must, however, continue to explore and improve this system in order to produce the simple exacting method sought years ago when improvements on TDN were necessary.

CHAPTER II

THE DEVELOPMENT OF FORMULAS FOR DETERMINING TOTAL NET ENERGY FOR MAINTENANCE AND GAIN

The Development of Formulas for Determining Total Net Energy for Maintenance in Multiphase Treatments (TMT)

To determine the net energy for maintenance (NEm) at any moment the following formula was used

$$NEm = .077W^{0.75}$$

where NEm is in megacalories (Mcal.) per day and W is body weight in kg.

In computing the total NEm or net energy for gain (NEg) over a period of time it was necessary to account for the change in weight to a power and subsequently the change in NEm or NEg per unit time. The procedure to follow was used in deriving formulas which would account for the total NEm, and later NEg, required by beef heifers or steers as W changed with time in a multi or single phase TMT feeding regime.

$$NEm = .077(Wo + gt)^{0.75} \qquad (1)$$

where Wo is the initial weight in kg, g is ADG in kg, and t is time in days.

In a two phase TMT the calculation for NEm in the second phase would be

$$NEm = .077(Wo + F + g_1t_1)^{0.75} \qquad (2)$$

where F is the final weight at the end of phase one and g_1 and t_1 are the second phase correspondents of g and t. Equations, such as these, could be set up for any number of phases by following the same pattern. The discussion here, however, will be limited to a two phase calculation. If P equals the first phase of a two phase TMT, equation (1) becomes

$$(NEm)_P = .077(Wo + gt)^{0.75} \qquad (3)$$

If Q equals the second phase of a two phase TMT, equation (2) becomes

$$(NEm)_Q = .077(Wo_f + g_1t_1)^{0.75} \qquad (4)$$

where $Wo_f = Wo + F$.

The solving of these equations, for each day from the first day, where t = 1, to the last day of the TMT or phase provides the total $(NEm)_P$ and/or $(NEm)_Q$. This method takes into account the change in Wo and subsequently the change in NEm with time in days. While g rises at a constant rate the exponent would tend to pull $(NEm)_{P\&Q}$ from linearity.

The problem with the discontinuous system employing equations (3) and (4) is that they must be solved the number of T times, where T is the total number of days in each phase, in both phases to yield the solution. For example, if there were 140 days in P and 55 days in Q these equations would have to be solved a total of 195 times; once for each day as follows

$$
\begin{aligned}
(NEm)_P = \; & .077(Wo + gx0)^{0.75} = \text{Mcal. for day one-P} \\
& .077(Wo + gx1)^{0.75} = \text{Mcal. for day two-P} \\
& .077(Wo + gx2)^{0.75} = \text{Mcal. for day three-P} \\
& \vdots \\
& .077(o + gx140)^{0.75} = \text{Mcal. for day 140-P}
\end{aligned}
$$

where the summation of these values is the total $(NEm)_P$ required. And

$$
\begin{aligned}
(NEm)_Q = \; & .077(Wo_f + g_1x0)^{0.75} = \text{Mcal. for day one-Q} \\
& .077(Wo_f + g_1x1)^{0.75} = \text{Mcal. for day two-Q} \\
& .077(Wo_f + g_1x2)^{0.75} = \text{Mcal. for day three-Q} \\
& \vdots \\
& .077(Wo_f + g_1x55)^{0.75} = \text{Mcal. for day 55-Q}
\end{aligned}
$$

where the summation of these values is the total $(NEm)_Q$ required.

These cumbersome calculations can, however, be condensed to one equation per phase while yielding approximately the same total NEm. This is accomplished by applying integration procedures to equations (3) and (4).

$$(NEm)_P = \int_0^T .077(Wo + gt)^{0.75}dt \qquad (5)$$

$$(NEm)_Q = \int_0^T .077(Wo_f + g_1 t_1)^{0.75} dt \qquad (6)$$

Using equation (5) as a model and pulling the constant

$$(NEm)_P = .077 \int_0^T (Wo + gt)^{0.75} dt \qquad (5)$$

Let

$$x = Wo + gt$$

then

$$dx = gdt$$

and

$$\frac{1}{g}dx = dt$$

Now

$$\int (Wo + gt)^{0.75} dt = \int x^{0.75} \left(\frac{1}{g} dx\right)$$

and since g is constant

$$\int x^{0.75} \left(\frac{1}{g} dx\right) = \frac{1}{g} \int x^{0.75} dx$$

Using the elementary integral form

$$\int x^n dx = \frac{x^{n+1}}{n+1} \qquad \text{except where } n = -1^1$$

we obtain

$$\frac{1}{g} \int x^{0.75} dx = \frac{1}{g} \cdot \frac{x^{1.75}}{1.75}$$

and replacing x

$$\frac{1}{g} \cdot \frac{(Wo + gt)^{1.75}}{1.75}$$

Using the original equation and applying the limits

$$(NEm)_P = \frac{.077}{g \cdot 1.75} (Wo + gt)^{1.75} \Big|_0^T$$

Placing the limits inside the equation we obtain

$$(NEm)_P = \frac{.044}{g}\left[(Wo + gT)^{1.75} - Wo^{1.75}\right] \quad (7)$$

where g_1t_1 drops out of the lower limit as $g = 0$.

Subjecting equation (6) to the same integration, equation (8) is obtained.

$$(NEm)_Q = \frac{.044}{g}\left[(Wo_f + g_1T_1)^{1.75} - Wo^{1.75}\right] \quad (8)$$

Solving equations (7) and (8) will provide the same result as all the calculations necessary solving with equations (3) and (4).

The Development of Formulas for Determining Total Net Energy for Gain in Multiphase Treatments.

Through the use of the above procedures, similar equations can be derived for total NEg.

The NEg for heifers is

$$NEg = (56.03g + 12.65g^2)\cdot(W^{0.75})$$

Where NEg is in kcal.

The NEg for steers is

$$NEg = (52.72g + 6.84g^2).(W^{0.75})$$

where NEg is in kcal.

As per equations (3) and (4), and using the Neg for heifers

$$(NEg)_P = (56.03g + 12.65g^2).(Wo + gt)^{0.75} \qquad (9)$$

and

$$(NEg)_Q = (56.03g_1 + 12.65g_1{}^2).(Wo_f + g_1t_1)^{0.75} \qquad (10)$$

Since $(56.03g + 12.65g^2)$ is a constant in each phase because g is constant and, with division by 1000 to yield Mcal., the following is obtained:

$$(NEg)_P = K_P(Wo + gt)^{0.75} \qquad (11)$$

and

$$(NEg)_Q = K_Q(Wo_f + g_1t_1)^{0.75} \qquad (12)$$

where K_P is a constant representing

$$\frac{(56.03g + 12.65g^2)}{1000} \quad \text{for heifers}$$

and K_Q

$$\frac{(56.03g1 + 12.65g1^2)}{1000} \quad \text{for heifers}$$

Similar equations could be set up for steer constants. These equations, (11) and (12), could be solved T times as were equations (3) and (4), or integrated to a continuous curve as were (3) and (4) to yield

$$(NEg)_P = \int_0^T K_P(Wo + gt)^{0.75}dt \qquad (13)$$

and

$$(NEg)_Q = \int_0^T K_Q(Wo_f + g_1t_1)^{0.75}dt \qquad (14)$$

and finally

$$(NEg)_P = \frac{K_P}{g + 1.75}\left[(Wo + gt)^{1.75} - Wo^{1.75}\right] \qquad (15)$$

and

$$(NEg)_Q = \frac{K_Q}{g = 1.75}\left[(Wo_f + g_1 t_1)^{1.75} - Wo^{1.75}\right] \qquad (16)$$

If, however, the $(NEm)_P$ and $(NEm)_Q$ in Mcal. have been derived using equations (7) and (8), equations (15) and (16) can be more simplified. Using (15) and (7) as examples

$$(NEg)_P = \frac{K_P}{g \cdot 1.75}\left[(Wo + gt)^{1.75} - Wo^{1.75}\right] \qquad (15)$$

and

$$(NEm)_P = \frac{.044}{g}\left[(Wo + gt)^{1.75} - Wo^{1.75}\right] \qquad (7)$$

Let

$$\left[(Wo + gt)^{1.75} - Wo^{1.75}\right] = y$$

then

$$(NEg)_P = \frac{K_P}{g \cdot 1.75} \cdot y$$

and

$$(NEm)_P = \frac{.044}{g} \cdot y$$

solving for y in $(NEm)_P$

$$y = (NEm)_P \cdot \frac{g}{.044}$$

Substituting for y in $(NEg)_P$

$$(NEg)_P = \frac{K_P}{g \cdot 1.75} \cdot (NEm)_P \cdot \frac{g}{.044}$$

$$= \frac{K_P}{.044 \cdot 1.75} \cdot (NEm)_P$$

Finally

$$(NEg)_P = (NEm)_P \cdot \frac{K_P}{.077} \qquad (17)$$

Using the same procedure on equation (16), equation (18) is obtained for phase Q of NEg.

$$(NEg)_Q = (NEm)_Q \cdot \frac{K_P}{.077} \qquad (18)$$

where K_P and K_Q are the constants for heifers or steers and $(NEm)_P$, $(NEm)_Q$, $(NEg)_P$ and $(NEg)_Q$ are in Mcal.

In summary, four equations (7), (8), (17) and (18), herein formulas (A), (B), (C), and (D) have been derived to yield the total NEm and NEg per TMT in any single or multiphase feeding regime. They could be used to project the total NE requirements of any beef animal given the required variables.

Formula (A) (Corresponds to equation (7))

$$(NEm)_P = \frac{.044}{g}\left[(Wo + gT)^{1.75} - Wo^{1.75}\right] \qquad (A)$$

Formula (B) (Corresponds to equation (8))

$$(NEm)_Q = \frac{.044}{g}\left[(Wo_f + g_1T_1)^{1.75} - Wo^{1.75}\right] \qquad (B)$$

Formula (C) (Corresponds to equation (17))

$$(NEg)_P = (NEm)_P \cdot \frac{K_P}{.077} \qquad (C)$$

Formula (D) (Corresponds to equation (18))

$$(NEg)_Q = (NEm)_Q \cdot \frac{K_Q}{.077} \qquad (D)$$

<u>The Possibility of Using Less Rigorous But Slightly More Simplified Equations for the Calculation of Total NEm and NEg</u>

It should be noted that the change in $(NEm)_P$ with time, in limited testing with actual data, appeared linear by graphical methods (Figure 1). The change in $(NEm)_P$ was computed involving an exponent, 0.75, applied to the change in weight for which linearity would not be the expected result, since only one is a linear exponent. However, assuming this linearity exists, and using the midpoint NEm and multiplying by T

$$(NEm)_P = T \cdot \left[.077(Wo + g\tfrac{T}{2})^{0.75}\right] \qquad (19)$$

approximately the same answer was obtained as was obtained with formula (A), while using some of the TMT data presented later in this thesis. The author was unable to account entirely for this phenomenon since he cannot prove:

$$\frac{.044}{g}\left[(Wo+gT)^{1.75} - Wo^{1.75}\right] = T \cdot \left[.077(Wo+g\tfrac{T}{2})^{0.75}\right] \qquad (20)$$

Formula (A) Equation (19)

The lack of linearity for equations with the form y^n, where $n \neq 1$, can be illustrated in the graphical representation using hypothetical situations. Figure 2 shows

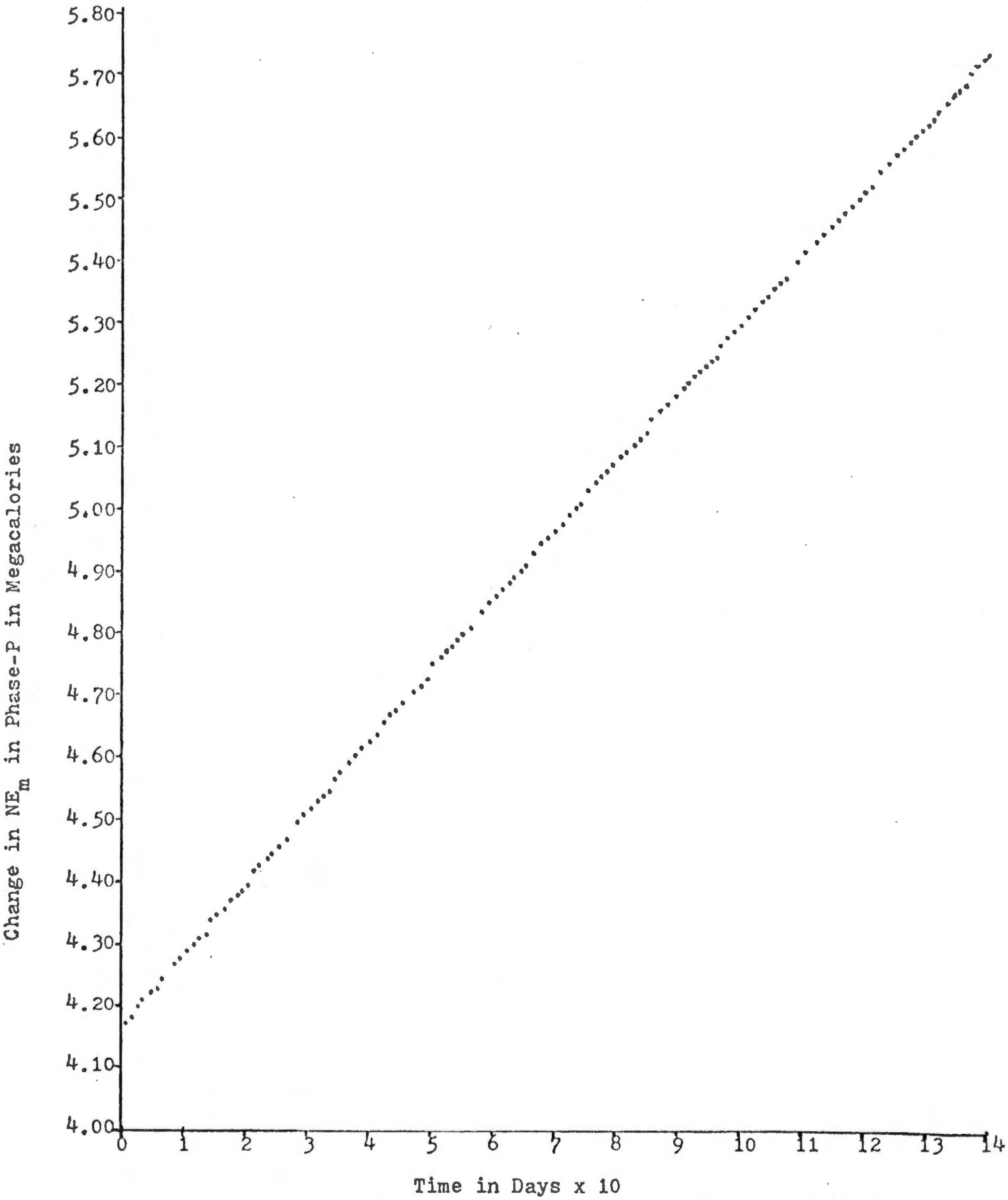

Figure 1. The Apparently Linear Relation between the Change in NE_m-P with Time in Treatment #1 of H-72-KB-3.

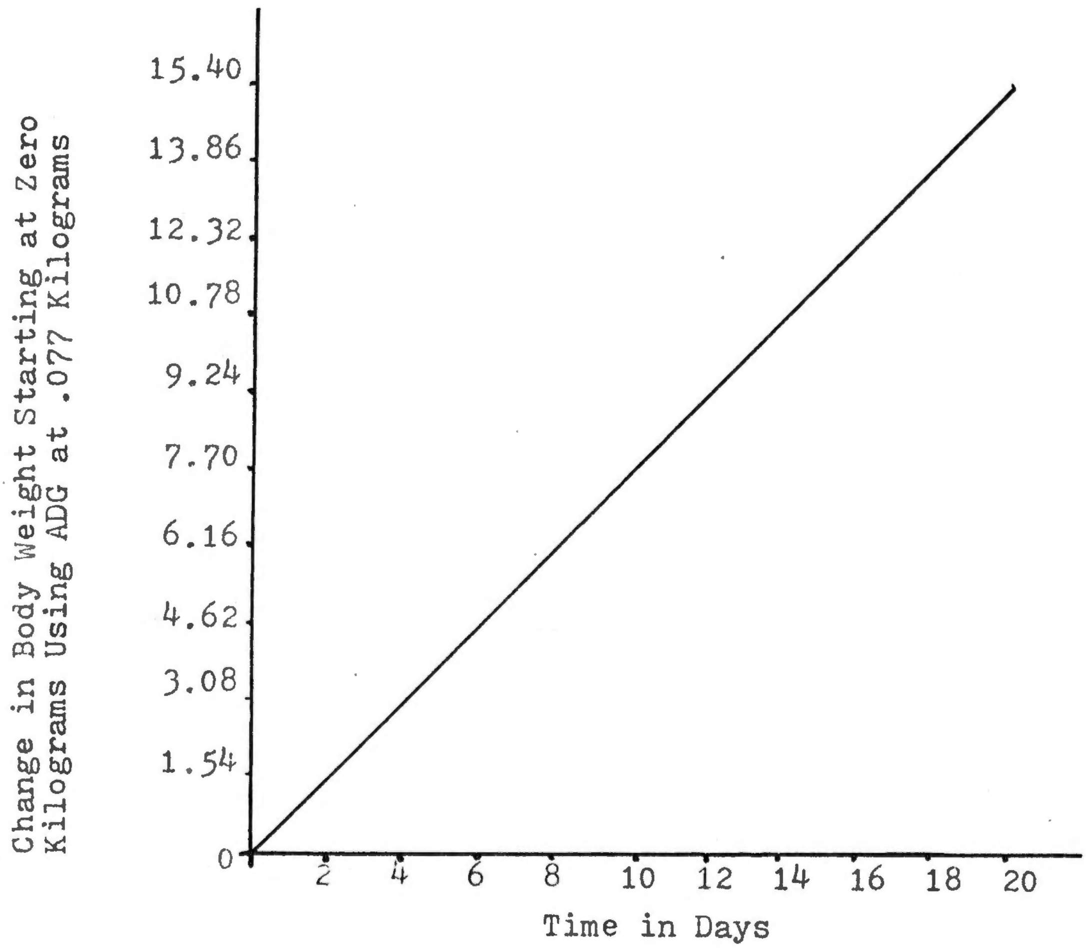

Figure 2. Linear Weight/Time Relation of ADG Without Exponent.

the change in g is linear but that when subjected to a power other than one, it is no longer linear.
If, for example, we set up

$$(NEm)_p = .077(Wo + gt)^{0.75}$$

where Wo = 4.6 kg, g = 0.89 kg and T = 20, the lack of linearity is apparent (Figure 3).

It is believed the reason that equation (19) works in this case is due to the relative magnitude of the change in $(NEm)_p$ above Wo (Figure 4). Using the data from a TMT tested later in this thesis as an example in Figure 4 it can be seen that the change in $(NEm)_p$ with time required over the $(NEm)_p$ required by the initial weight (Wo) is small. The difference between equation (19) and formula (A) is the small difference between the slight curvilinearity produced by the exponent, 0.75, and the linear expression of equation (19). The reason for the apparent useability of average values to solve for total $(NEm)_p$ in this kind of situation, then, is simply due to the fact that the difference between linearity and curvilinearity is a small part of a small part of the total area under the curve.

Formulas (A), (B), (C) and (D) are mathematically rigorous and, thereby correct for any TMT variables for which they may be employed. For this reason, they will be set forth as the method of choice in computing total NEm and NEg. Further investigation should be made to determine the relation between formula (A) and equation (19) and

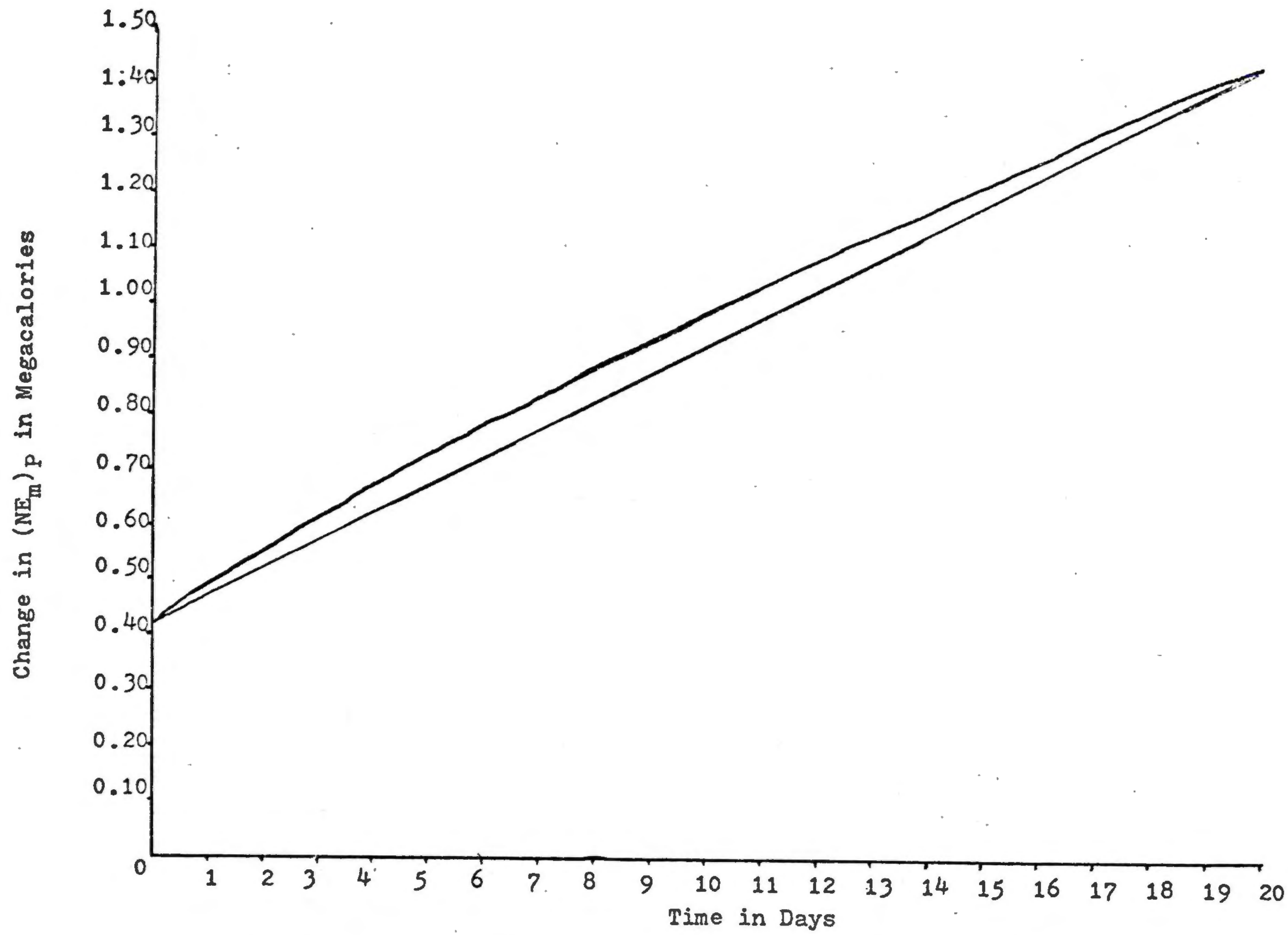

Figure 3. Example Where Wo = 4.6 Kilograms, g = 0.89 Kilograms and T = 20 Days.

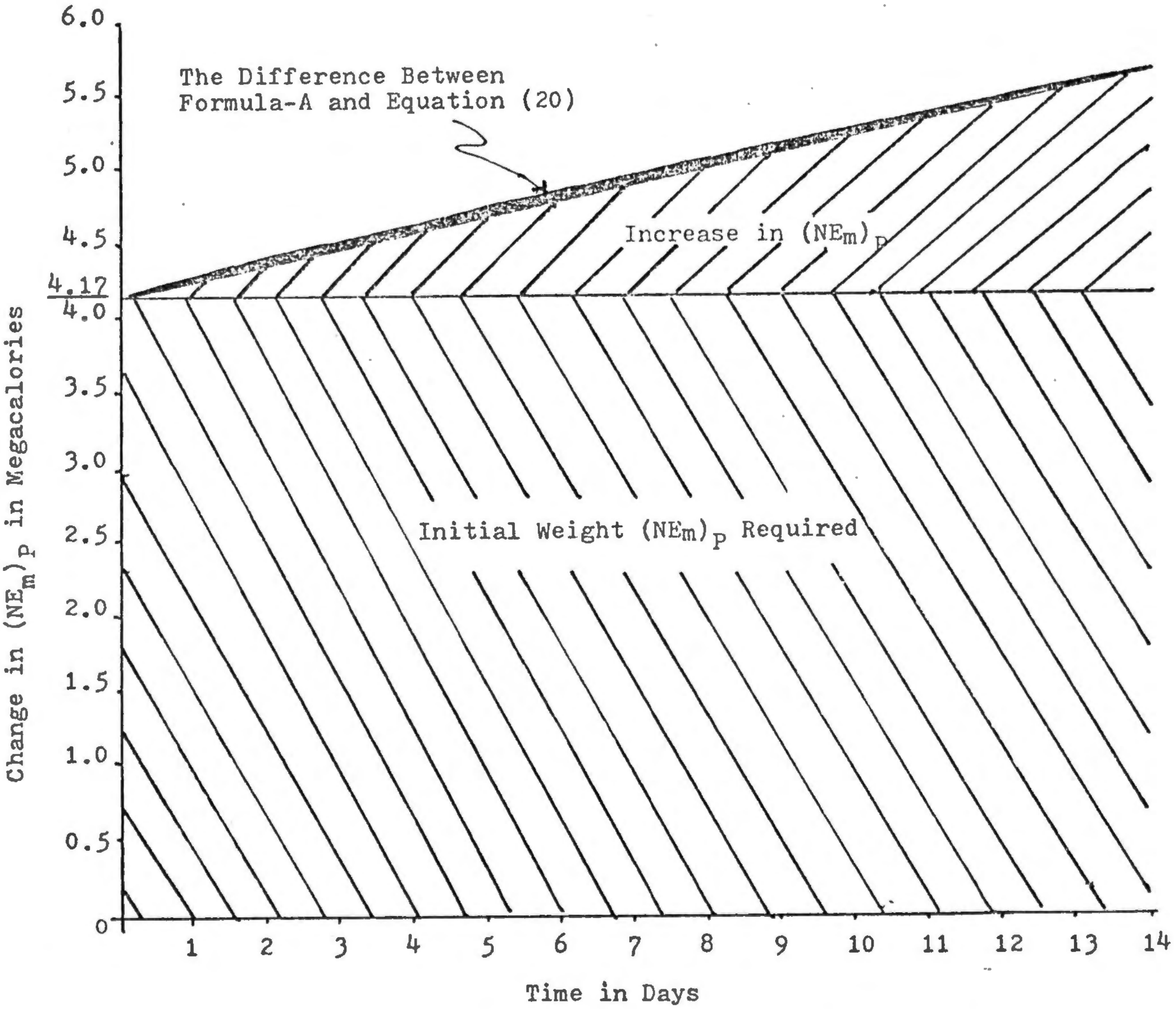

Figure 4. The Relative Magnitude of the Change in $(NE_m)_P$ - Initial versus $(NE_m)_P$ Increase above Initial Weight.

for the formula (B), (C) and (D) correspondence of equation (19). A future study could test a large number of TMT to see if equation (19), although not mathematically rigorous, might work reasonably well within the normal limits of beef cattle feeding programs.

CHAPTER III

THE APPLICATION OF FORMULAS (A), (B), (C) AND (D) TO THE DATA FROM H-72-KB-3

The application and testing of this method of determining total net energy will be carried out in a number of steps, of which this is the first, employing the data from a study conducted at The University of Tennessee in the years 1967 and 1968 and labeled H-72-KB-3. This chapter uses the data provided by this experiment to satisfy the variables of equations (A), (B), (C) and (D) in predicting the total net energy requirement. Later chapters, expressing the predicted NEm&g in terms of feed required, will test the results of the predicted figures obtained here with the actual consumption data of the original experiment.

Original TMT Methods of H-72-KB-3

In order to understand more fully how total NEm&g is computed in multiphase TMT and to familiarize the reader with the original feeding regime, a brief description of the TMT in H-72-KB-3 is required.

The experiment involved the feeding of urea-limestone treated corn silage (CS) with variable amounts of concentrates to feeder heifers. Of the TMT phases the first was a roughage phase utilizing urea-limestone corn silage plus supplement, and the second was a fullfeed phase employing ground shelled corn (GSC) plus supplement. The TMT tested in this report were as follows:

TMT-1: CS, ad libitum, plus six pounds of concentrate daily. After the first 140 days fullfeed. Urea and limestone were added at the rate of 10 pounds, each, per ton of green chop. This TMT represented the control.

TMT-4: Same as control but no corn for the first 56 days.

TMT-5: Same as control but no corn for the first 84 days.

TMT-6: Same as control but no corn for the first 112 days.

TMT-7: Same as control but no corn for the first 140 days.

TMT-8: CS, ad libitum, plus one pound of cottonseed meal (CSM) for 168 days; thereafter fullfeed.

TMT-11: Same as control but urea added at the rate of 15 pounds per ton of green chop.

TMT-12: Same as control except urea added at the rate of 20 pounds per ton of green chop.

Computation of Total NEm&g in these TMT

The variables of formulas (A), (B), (C) and (D) will be met employing the actual data of H-72-KB-3 in computing the NEm&g for all TMT. The data from phase-P of TMT-1 only will be used to illustrate possibility of using equations (3) or (19) in computing (NEm)p.

TMT-1

An example of using equation (3) for computing the $(NEm)_P$

$$(NEm)_P = .077(Wo + gt)^{0.75} \qquad (3)$$

where Wo = 206 kg, g = 0.77 kg and t goes from 0 to 140 days.

Then

$$(NEm)_P = .077(206 + 0.77 \cdot 0)^{0.75} = 4.186 \text{ Mcal.}$$

$$= .077(206 + 0.77 \cdot 1)^{0.75} = 4.198 \text{ Mcal.}$$

$$= .077(206 + 0.77 \cdot 2)^{0.75} = 4.210 \text{ Mcal.}$$

$$\vdots$$

$$= .077(206 + 0.77 \cdot 140)^{0.75} = 5.741 \text{ Mcal.}$$

where the total $(NEm)_P$ is the summation of these values.

An example using equation (19) for computation of $(NEm)_P$

$$(NEm)_P = T \cdot \left[.077(Wo + g\frac{T}{2})^{0.75}\right] \tag{19}$$

where T = 140 days, Wo = 206 kg and g = 0.77 kg.

Then

$$\begin{aligned}(Nem)_P &= \left[140 \cdot \ .077(206 + 0.77\frac{140}{2})^{0.75}\right] \\ &= 140 \cdot \left[4.984\right] \\ &= 698 \text{ Mcal.}\end{aligned}$$

where $\left[4.984\right]$ = the Mcal. at day 70.

The computation of $(NEm)_{P\&Q}$ and $(NEg)_{P\&Q}$ employing formulas (A), (B), (C) and (D) for TMT 1, 4-8, 11 and 12. (See pages 30 and 31 for these formulas.) Note that although all the variables here are given by previous experimental data, it would be possible to set up the desired variables of a projected feeding program and thereby obtain the projected total $(NEm)_{P\&Q}$ and $(NEg)_{P\&Q}$. This fact will become important later since it could help determine the total projected consumption.

TMT-1

$(NEm)_P$: where g = 0.77 kg, Wo = 206 kg and T = 140 days.

$$= \frac{.044}{0.77}\left[(206 + 0.77 \cdot 140)^{1.75} - 206^{1.75}\right] \qquad \text{Formula (A)}$$

$$= .057\left[23396 - 11201\right] = 695 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 0.99 kg, Wo_f = kg and T = 55 days.

$$= \frac{.044}{0.99}\left[(314 + 0.99 \cdot 55)^{1.75} - 314^{1.75}\right] \qquad \text{Formula (B)}$$

$$= .044\left[30956 - 23396\right] = 333 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 1028 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 695 Mcal. and K_P = .0506

$$= 695 \cdot \frac{.0506}{.077} = 457 \text{ Mcal.} \qquad \text{Formula (C)}$$

$(NEg)_Q$: where $(NEm)_Q$ = 333 Mcal. and K_Q = .0679

$$333 \cdot \frac{.0679}{.077} = 294 \text{ Mcal.} \qquad \text{Formula (D)}$$

where the total $(NEg)_{P\&Q}$ = 751 Mcal.

TMT-4

$(NEm)_P$: where g = 0.71 kg, Wo = 206 kg, T = 140 days

$$= \frac{.044}{0.71}\left[(206 + 0.71 \cdot 140)^{1.75} - 206^{1.75}\right]$$

$$= .062\left[22311 - 11201\right] = 689 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 1.03 kg, Wo_f = 305 kg, T = 55 days

$$= \frac{.044}{1.03}\left[(305 + 1.03 \cdot 55)^{1.75} - 305^{1.75}\right]$$

$$= .043\left[29992 - 22260\right] = 333 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 1022 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 689 Mcal. and K_P = .0462

$$= 689 \cdot \frac{.0462}{.077} = 413 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 333 Mcal. and K_Q = .0711

$$= 333 \cdot \frac{.0711}{.077} = 308 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 721 Mcal.

TMT-5

$(NEm)_P$: where g = 0.65 kg, Wo = 204 kg, T = 140 days

$$= \frac{.044}{0.65}\left[(204 + 0.65 \cdot 140)^{1.75} - 204^{1.75}\right]$$

$$= .068\left[20999 - 11012\right] = 679 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 1.07 kg, Wo_f = 295 kg, T = 55 days

$$= \frac{.044}{1.07}\left[(295 + 1.07 \cdot 55)^{1.75} - 295^{1.75}\right]$$

$$= .041\left[28891 - 20998\right] = 324 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 1003 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 679 Mcal. and K_p = .0418

$$= 679 \cdot \frac{.0418}{.077} = 369 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 324 Mcal. and K_p = .0744

$$= 324 \cdot \frac{.0744}{.077} = 313 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 682 Mcal.

TMT-6

$(NEm)_P$: where g = 0.60 kg, Wo = 205 kg, T = 140 days

$$= \frac{.044}{0.60}\left[(205 + 0.60 \cdot 140)^{1.75} - 205^{1.75}\right]$$

$$= .073\left[20257 - 11106\right] = 668 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 1.09 kg, Wo_f = 289 kg, T = 55 days

$$= \frac{.044}{1.09}\left[(289 + 1.09 \cdot 55)^{1.75} - 289^{1.75}\right]$$

$$= .040\left[28173 - 20257\right] = 317 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 985 Mcal.

$(NEg)_P$: where $(NEm)_P$ = Mcal. and K_P = .0382

$$= 668 \cdot \frac{.0382}{.077} = 331 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 317 Mcal. and K_Q = .0761

$$= 317 \cdot \frac{.0761}{.077} = 313 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 644 Mcal.

TMT-7

$(NEm)_P$: where g = 0.60 kg, Wo = 204 kg, T = 140 days

$$= \frac{.044}{0.60}\left[(204 + 0.60 \cdot 140)^{1.75} - 204^{1.75}\right]$$

$$= .073\left[20134 - 11012\right] = 666 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 1.03 kg, Wo_f = 288 kg, T = 55 days

$$= \frac{.044}{1.03}\left[(288 + 1.03 \cdot 55)^{1.75} - 288^{1.75}\right]$$

$$= .043\left[27568 - 20134\right] = 320 \text{ Mcal.}$$

where the total $(NEm)_P$ = 986 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 666 and K_P = .0382

$$= 666 \cdot \frac{.0382}{.077} = 330 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 320 Mcal. and K_Q = .0711

$$= 320 \cdot \frac{.0711}{.077} = 296 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 626 Mcal.

TMT-8

$(NEm)_P$: where g = 0.65 kg, Wo = 205 kg, T = 168 days

$$= \frac{.044}{0.68}\left[(205 + 0.65 \cdot 168)^{1.75} - 205^{1.75}\right]$$

$$= .068\left[23448 - 11106\right] = 839 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 0.96 kg, Wo_f = 314 kg, T = 27 days

$$= \frac{.044}{0.96}\left[(314 + 0.96 \cdot 27)^{1.75} - 314^{1.75}\right]$$

$$= .046\left[26910 - 23422\right] = 160 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 999 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 839 Mcal. and K_P = .0418

$$= 839 \cdot \frac{.0418}{.077} = 456 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 160 Mcal. and K_Q = .0654

$$= 160 \cdot \frac{.0654}{.077} = 136 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 592 Mcal.

TMT-11

$(NEm)_P$: where g = 0.75, Wo = 205 kg, T = 140 days

$$= \frac{.044}{0.75}\left[(205 + 0.75\cdot 140)^{1.75} - 205^{1.75}\right]$$

$$= .059\left[22903 - 11106\right] = 696 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 0.97 kg, Wo_f = 310 kg, T = 55 days

$$= \frac{.044}{0.97}\left[(310 + 0.97\cdot 55)^{1.75} - 310^{1.75}\right]$$

$$= .045\left[30239 - 22903\right] = 330 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 1026 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 696 Mcal. and K_P = .0491

$$= 696\cdot\frac{.0491}{.077} = 444 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_P$ = 330 Mcal. and K_P = .0663

$$= 330\cdot\frac{.0663}{.077} = 284 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 728 Mcal.

TMT-12

$(NEm)_P$: where g = 0.80 kg, Wo = 206 kg, T = 140 days

$$= \frac{.044}{0.80}\left[(206 + 0.80\cdot140)^{1.75} - 206^{1.75}\right]$$

$$= .055\left[23947 - 11201\right] = 701 \text{ Mcal.}$$

$(NEm)_Q$: where g_1 = 0.96 kg, Wo_f = 318 kg, T = 55 days

$$= \frac{.044}{0.96}\left[(318 + 0.96\cdot55)^{1.75} - 318^{1.75}\right]$$

$$= .046\left[31333 - 23947\right] = 340 \text{ Mcal.}$$

where the total $(NEm)_{P\&Q}$ = 1041 Mcal.

$(NEg)_P$: where $(NEm)_P$ = 701 Mcal. and K_P = .0529

$$= 701\cdot\frac{.0529}{.077} = 482 \text{ Mcal.}$$

$(NEg)_Q$: where $(NEm)_Q$ = 340 Mcal. and K_Q = .0655

$$= 340\cdot\frac{.0655}{.077} = 289 \text{ Mcal.}$$

where the total $(NEg)_{P\&Q}$ = 771 Mcal.

CHAPTER IV

COMPUTING THE NEm AND NEg PROVIDED BY TWO METHODS

The next step, in determining the credibility and applicability of formulas (A), (B), (C), and (D), is to calculate the values for NEm and NEg provided by the feeds. These values may then be divided into the megacalories required, earlier computed, to yield an approximation of the total ration necessary. The amount of ration actually consumed in H-72-KB-3 can then be compared with this calculated value as a test of the formulas. The NEm and NEg provided by the rations in these TMT will be calculated by two different methods. The first will be simply a weighted average of components and, the second will be the corn/corn silage associative calculation as submitted by Byers, Matsushima and Johnson (1974). Later, projected consumption figures obtained with the use of these two methods and calculated as described above, will be compared against the actual consumption records of H-72-KB-3 by statistical methods. These methods, then, will eventually test the practical value of formulas (A), (B), (C) and (D) and the accuracy of weighted averages versus associative calculations.

The NEm and NEg of Multicomponent Rations in Each Phase of Each TMT by Weighted Percent

The dry matter percent and the percent of each component per phase per TMT were obtained from the original study.

The NE content of ration components were obtained from the NRC publication four on beef cattle requirements. The results appear as Mcal. per pound in order to conform with the units of the original study. The calculations for this method are self-explanatory when presented in tabular form. Therefore, the NEm and NEg provided by the rations in each phase of each TMT of H-72-KB-3 appear in table 1.

The NEm and NEg of Phase-P of Each TMT by the Associative Method

Only phase-P will be calculated and compared by this method as it is the phase in all TMT which contains the CS necessary for expression of the associative interaction. It is necessary to know the total corn for computation and for this reason the silage was estimated to contain 40% corn grain.

The associative formulas for the NEm and NEg of a corn/ corn silage ration are

$$NEm = 6.449 \cdot 10^{-7} (\% \text{ Total corn})^3 + 1.72 \qquad \text{(RA)}$$

$$NEg = 8.491 \cdot 10^{-5} (\% \text{ Total corn})^2 + 1.24 \qquad \text{(RB)}$$

where NEm and NEg are in kilocalories per gram, which is equivalent to megacalories per kilogram.

As was the case in earlier chapters, TMT-1 will be a more in depth explanation of the method. The NEm or NEg of the components other than corn or corn silage were obtained from the NRC handbook

TABLE 1. The NEm and NEg Provided by the Ration in Each Phase of Each TMT of H-72-KB-3 by the Weighted Percent Method

TMT	Phase	% Ration Component	% DM	Mcal./lb.[5] DM Basis NEm	Mcal./lb.[5] DM Basis NEg	Mcal./lb. As Fed NEm	Mcal./lb. As Fed NEg	% Feed Value NEm	% Feed Value NEg	Total Mcal./lb. Provided (NEm)PR[6]/QR	Total Mcal./lb. Provided (NEg)PR[7]/QR
1	P	CS[1] - 80	36	0.71	0.45	0.26	0.16	0.21	0.13		
		GSC[2] - 18	89	1.04	0.67	0.93	0.60	0.17	0.11		
		CSM[3] - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.40	0.25
	Q	ALF[4] - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51
4	P	CS - 87	36	0.71	0.45	0.26	0.16	0.23	0.14		
		GSC - 11	89	1.04	0.67	0.93	0.60	0.10	0.07		
		CSM - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.35	0.22
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51
5	P	CS - 91	36	0.71	0.45	0.26	0.16	0.24	0.15		
		GSC - 07	89	1.04	0.67	0.93	0.60	0.07	0.04		
		CSM - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.33	0.20
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51

TABLE 1. (continued)

TMT	Phase	% Ration Component	% DM	Mcal./lb. DM Basis NEm	Mcal./lb. DM Basis NEg	Mcal./lb. As Fed NEm	Mcal./lb. As Fed NEg	% Feed Value NEm	% Feed Value NEg	Total Mcal./lb. Provided (NEm) PR/QR	Total Mcal./lb. Provided (NEg) PR/QR
6	P	CS - 94	36	0.71	0.45	0.26	0.16	0.24	0.15		
		GSC - 04	89	1.04	0.67	0.93	0.60	0.04	0.02		
		CSM - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.30	0.18
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51
7	P	CS - 97	36	0.71	0.45	0.26	0.16	0.25	0.16		
		GSC - 00	89	1.04	0.67	0.00	0.00	0.00	0.00		
		CSM - 03	92	0.82	0.55	0.75	0.51	0.02	0.02	0.27	0.18
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51
8	P	CS - 97	36	0.71	0.45	0.26	0.16	0.25	0.16		
		GSC - 00	89	1.04	0.67	0.00	0.00	0.00	0.00		
		CSM - 03	92	0.82	0.55	0.75	0.51	0.02	0.02	0.27	0.18
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51

TABLE 1. (continued)

TMT	Phase	% Ration Component	% DM	Mcal./lb. DM Basis NEm	NEg	Mcal./lb. As Fed NEm	NEg	% Feed Value NEm	NEg	Total Mcal./lb. Provided (NEm)PR/QR	(NEg)PR/QR
11	P	CS - 78	36	0.71	0.45	0.26	0.16	0.20	0.12		
		GSC - 20	89	1.04	0.67	0.93	0.60	0.19	0.12		
		CSM - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.41	0.25
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51
12	P	CS - 79	36	0.71	0.45	0.26	0.16	0.21	0.13		
		GSC - 19	89	1.04	0.67	0.93	0.60	0.18	0.11		
		CSM - 02	92	0.82	0.55	0.75	0.51	0.02	0.01	0.41	0.25
	Q	ALF - 21	95	0.61	0.22	0.58	0.21	0.12	0.04		
		GSC - 70	89	1.04	0.67	0.93	0.60	0.65	0.42		
		CSM - 09	92	0.82	0.55	0.75	0.51	0.07	0.05	0.84	0.51

[1] CS = Urea-limestone corn silage.

[2] GSC = Ground shelled corn.

[3] CSM = Cottonseed meal.

[4] ALF = Alfalfa.

[5] Values obtained from Handbook #4. Nutritional requirements of beef cattle. NRS/NRC. 1970.

[6] $(NEm)_{PR/QR}$ = The NEm provided per lb. of ration in phase-P and in phase-Q.

[7] $(NEg)_{PR/QR}$ = The NEg provided per lb. of ration in phase-P and in phase-Q.

CS + GSC = 98% of the ration
80% - CS at 40% corn
18% - GCS at 100% corn

49% total corn (where 98 = 100% of ration)

$$(NEm)_{PR} = 6.449 \cdot 10^{-7} \cdot (49)^3 + 1.72 = 1.79 \text{ Mcal./kg DM}$$

using formula (RA).

$$1.79 \div 2.2 = 0.81 \text{ Mcal./lb. of DM}$$

where the conversion to pounds is in order to conform to the units of the original study for later testing.

CS-DM = 35.70 @ 80% of ration
GSC-DM = 89.00 @ 18% of ration

= 44.6% DM/lb. or 7.2 oz./lb. DM

and

$$\frac{16}{7.2} :: \frac{0.81}{x} = \frac{5.84}{16} = 0.36 \text{ Mcal./lb. as fed}$$

or

$$0.81 \cdot 0.446 = 0.36 \text{ Mcal./lb.}$$

which will be the method of choice.

$$(NEg)_{PR} = 8.491 \cdot 10^{-5} \cdot (49)^2 + 1.24 = 1.44 \text{ Mcal./kg DM}$$

using formula (RB).

$$1.44 \div 2.2 = 0.65 \text{ Mcal./lb. DM}$$

where the conversion to pounds is as (RA).

$$0.65 \cdot 0.446 = 0.29 \text{ Mcal./lb. as fed}$$

as per the "or" method of (RA) above.

Now adding the energy provided by CSM for $(NEm)_{PR}$ and $(NEg)_{PR}$ we obtain

$$(NEm)_{PR} = \begin{array}{l} 0.98 \cdot 0.36 = 0.350 \\ 0.02 \cdot 0.75 = \underline{0.015} \\ \qquad\qquad\quad 0.365 \text{ Mcal./lb.} \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.37</u> Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{l} 0.98 \cdot 0.29 = 0.280 \\ 0.02 \cdot 0.51 = \underline{0.009} \\ \qquad\qquad\quad 0.289 \text{ Mcal./lb.} \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.29</u> Mcal./lb.

The remaining TMT will be computed following this form. The final $(NEm)_{PR}$ and $(NEg)_{PR}$ values in each TMT will be underlined for the sake of clarity.

TMT-4

CS + GSC = 98% of ration
87% CS @ 40% corn
11% GSC @ 100% corn

= 45% total corn

$$(NEm)_{PR} = 6.449 \cdot 10^{-7} \cdot (45)^3 + 1.72 = 1.77 \text{ Mcal./kg DM}$$

$$= 0.80 \text{ Mcal./lb. DM}$$

CS - DM = 35.70 @ 87% of ration
GSC - DM = 89.00 @ 11% or ration

= 40·8% DM/lb.

$0.80 \cdot 0.408 = 0.33$ Mcal./lb. as fed

$$(NEg)_{PR} = 8.491 \cdot 10^{-5} \cdot (45)^2 + 1.25 = 1.44 \text{ Mcal./kg DM}$$

$$= 0.64 \text{ Mcal./lb. DM}$$

$0.64 \cdot 0.408 = 0.26$ Mcal./lb. as fed

then

$$(NEm)_{PR} = \begin{array}{l} 0.98 \cdot 0.33 = 0.320 \\ 0.02 \cdot 0.75 = \underline{0.015} \\ \qquad\qquad\quad 0.335 \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.34</u> Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{l} 0.98 \cdot 0.26 = 0.250 \\ 0.02 \cdot 0.51 = \underline{0.009} \\ \qquad\qquad\quad 0.259 \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.26</u> Mcal./lb.

TMT-5

CS + GSC = 98% of ration
91% CS @ 40% corn
07% GSC @ 100% corn

= 43% total corn

$$(NEm)_{PR} = 6.449 \cdot 10^{-7}(43)^3 + 1.72 = 1.77 \text{ Mcal./kg DM}$$

= 0.80 Mcal./lb. DM

CS - DM = 35.70 @ 91%
GSC - DM = 89.00 @ 07%

= 38.7% DM/lb.

0.80·0.387 = 0.31 Mcal./lb. as fed

$$(NEg)_{PR} = 8.491 \cdot 10^{-5}(43)^2 + 1.24 = 1.39 \text{ Mcal./kg DM}$$

= 0.63 Mcal./lb. DM

0.63·0.387 = 0.24 Mcal./lb. as fed

then

$$(NEm)_{PR} = \begin{array}{l} 0.98 \cdot 0.31 = 0.300 \\ 0.02 \cdot 0.75 = \underline{0.015} \\ \qquad\qquad\quad 0.315 \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.32</u> Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{l} 0.98 \cdot 0.24 = 0.240 \\ 0.02 \cdot 0.51 = \underline{0.009} \\ \qquad\qquad\quad 0.249 \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.25</u> Mcal./lb.

TMT-6

CS + GSC + 98% of ration
94% CS @ 40% corn
04% GSC @ 100% corn

= 41% total corn

$$(NEm)_{PR} = 6.449 \cdot 10^{-7}(41)^3 + 1.72 = 1.76 \text{ Mcal./kg DM}$$

= 0.80 Mcal./lb. DM

CS - DM = 35.70 @ 94%
BSC - DM = 89.00 @ 04%

= 33.6% DM/lb.

0.80•0.336 = 0.27 Mcal./lb. as fed

$$(NEg)_{PR} = 8.491 \cdot 10^{-5}(41)^2 + 1.24 = 1.38 \text{ Mcal.}$$

= 0.63 Mcal./lb. DM

0.63•0.336 = 0.21 Mcal./lb. as fed

then

$$(NEm)_{PR} = \begin{array}{rl} 0.98 \cdot 0.27 = & 0.260 \\ 0.02 \cdot 0.75 = & \underline{0.015} \\ & 0.275 \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.28</u> Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{rl} 0.98 \cdot 0.21 = & 0.210 \\ 0.02 \cdot 0.51 = & \underline{0.009} \\ & 0.219 \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.22</u> Mcal./lb.

TMT-7

No GSC in phase-P; therefore, no associative interaction and no calculation by this method.

TMT-8

No GSC in phase-P; therefore, as TMT-7.

TMT-11

CS + GSC = 98% of ration
78% CS @ 40% corn
20% GSC @ 100% corn

= 50% total corn

$$(NEm)_{PR} = 6.449 \cdot 10^{-7}(50)^3 + 1.72 = 1.80 \text{ Mcal./kg DM}$$

$$= 0.82 \text{ Mcal./lb. DM}$$

CS - DM = 35.70 @ 78%
GSC - DM = 89.00 @ 20%

= 45.7% DM/lb.

$0.82 \cdot 0.457 = 0.37$ Mcal./lb. as fed

$$(NEg)_{PR} = 8.491 \cdot 10^{-5}(50)^2 + 1.24 = 1.44 \text{ Mcal./kg DM}$$

$$= 0.65 \text{ Mcal./lb. DM}$$

$0.65 \cdot 0.457 = 0.37$ Mcal./lb. as fed

then

$$(NEm)_{PR} = \begin{array}{l} 0.98 \cdot 0.37 = 0.360 \\ 0.02 \cdot 0.75 = \underline{0.015} \\ \qquad\qquad\quad 0.375 \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.38</u>, Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{l} 0.98 \cdot 0.30 = 0.290 \\ 0.02 \cdot 0.51 = \underline{0.009} \\ \qquad\qquad\quad 0.299 \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.30</u> Mcal./lb.

TMT-12

CS + GSC = 98% of ration
79% CS @ 40% corn
19% GSC @ 100% corn

= 50% total corn

$(NEm)_{PR} = 6.449 \cdot 10^{-7}(50) + 1.72 = 1.80$ Mcal./kg DM

$= 0.82$ Mcal./lb. DM

CS - DM = 35.70 @ 79%
GSC - DM = 89.00 @ 19%

= 45.1% DM/lb.

$0.82 \cdot 0.451 = 0.37$ Mcal./lb. fed

$(NEg)_{PR} = 8.419 \cdot 10^{-5}(50)^2 + 1.24 = 1.44$ Mcal./kg DM

$= 0.65$ Mcal./lb. DM

$0.65 \cdot 0.451 = 0.29$ Mcal./lb. as fed

then

$$(NEm)_{PR} = \begin{array}{l} 0.98 \cdot 0.37 = 0.360 \\ 0.02 \cdot 0.75 = \underline{0.015} \\ \qquad\qquad\quad 0.375 \end{array}$$

The total $(NEm)_{PR}$ provided equals <u>0.38</u> Mcal./lb.

and

$$(NEg)_{PR} = \begin{array}{l} 0.98 \cdot 0.29 = 0.280 \\ 0.02 \cdot 0.51 = \underline{0.009} \\ \qquad\qquad\quad 0.289 \end{array}$$

The total $(NEg)_{PR}$ provided equals <u>0.29</u> Mcal./lb.

The NEm and NEg provided by the rations as calculated by both methods appear in summary in Table 2 for easy comparison.

TABLE 2. The NEm and NEg Provided by the Rations in H-72-KB-3 by Weighted Averages and Associative Methods.

	Associative		Weighted Percent			
TMT	$(NEm)_{PR}$	$(NEg)_{PR}$	$(NEm)_{PR}$	$(NEg)_{PR}$	$(NEm)_{QR}$	$(NEg)_{QR}$
1	0.37	0.29	0.40	0.25	0.84	0.51
4	0.34	0.26	0.35	0.22	0.84	0.51
5	0.32	0.25	0.33	0.20	0.84	0.51
6	0.28	0.22	0.30	0.18	0.84	0.51
7	na[1]	na	0.27	0.18	0.84	0.51
8	na	na	0.27	0.18	0.84	0.51
11	0.38	0.30	0.41	0.25	0.84	0.51
12	0.38	0.29	0.41	0.25	0.84	0.51

[1]Not applicable.

CHAPTER V

COMPUTING THE PROJECTED CONSUMPTION

To this point the megacalories required, using formulas (A), (B), (C) and (D) and the megacalories provided in the ration using two methods have been calculated. Knowing these two values the projected consumption could be calculated by simple division. This projected figure can be compared against the actual consumption figures of H-72-KB-3. In this way the practical value of this method for estimating total NEm and NEg and subsequently total projected consumption can be tested.

$$\text{lbs. of feed required for NEm-P} = \frac{(\text{NEm})_P \text{ in Mcal.}}{(\text{NEm})_{PR} \text{ in Mcal./lb.}} \quad (20)$$

$$\text{lbs. of feed required for NEg-P} = \frac{(\text{NEg})_P \text{ in Mcal.}}{(\text{NEg})_{PR} \text{ in Mcal./lb.}} \quad (21)$$

$$\text{lbs. of feed required for NEm-Q} = \frac{(\text{NEm})_Q \text{ in Mcal.}}{(\text{NEm})_{QR} \text{ in Mcal./lb}} \quad (22)$$

$$\text{lbs. of feed required for NEg-Q} = \frac{(\text{NEg})_Q \text{ in Mcal.}}{(\text{NEg})_{QR} \text{ in Mcal./lb.}} \quad (23)$$

where the units of weight are a function of the divisor and are expressed here in pounds to conform with H-72-KB-3 units.

This procedure can be done using either the weighted average or associative method to obtain the divisor. However, only phase-P can be calculated here using the associative method since there were no associative interactions in phase-Q. The values obtained by both methods will be compared later to test their respective applicability. This is to say, to determine which when divided into the same numerator more closely approximates the actual values.

The results of applying equations (20), (21), (22) and (23) to the previous data is as follows:

TMT-1

	Total lbs./phase	
	Calculated	Actual
Employing equation (20)		
$NEm\text{-}P = \frac{695}{0.40} = 1738$ lbs.		
Employing equation (21)		
$NEg\text{-}P = \frac{457}{0.25} = 1828$ lbs.	3566	4200
Employing equation (22)		
$NEm\text{-}Q = \frac{333}{0.84} = 396$ lbs.		
Employing equation (23)		
$NEg\text{-}Q = \frac{294}{0.51} = 576$ lbs.	972	1007

TMT-1, using associative divisor.

	Calculated	Actual
Employing equation (20) again		
$NEm\text{-}P = \frac{695}{0.37} = 1878$ lbs.		
Employing equation (21) again		
$NEg\text{-}P = \frac{457}{0.29} = 1576$ lbs.	3454	4200

The remaining TMT will be computed following the method above.

TMT-4

	Total lbs./phase Calculated	Total lbs./phase Actual
NEm-P $= \frac{689}{0.35} =$ 1969 lbs.		
NEg-P $= \frac{413}{0.22} =$ 1877 lbs.	3846	4270
NEm-Q $= \frac{333}{0.84} =$ 396		
NEg-Q $= \frac{308}{0.51} =$ 604 lbs.	1000	1040

TMT-4, using associative divisor.

	Calculated	Actual
NEm-P $= \frac{689}{0.34} =$ 2027 lbs.		
NEg-P $= \frac{413}{0.26} =$ 1589 lbs.	3616	4270

TMT-5

	Calculated	Actual
NEm-P $= \frac{679}{0.33} =$ 2058 lbs.		
NEg-P $= \frac{369}{0.20} =$ 1845 lbs.	3903	4466
NEm-Q $= \frac{324}{0.84} =$ 386 lbs.		
NEg-Q $= \frac{313}{0.51} =$ 613 lbs.	999	1012

TMT-5, using associative divisor.

	Calculated	Actual
NEm-P $= \frac{679}{0.32} =$ 2100 lbs.		
NEg-P $= \frac{369}{0.25} =$ 1476 lbs.	3576	4466

TMT-6

	Total lbs./phase	
	Calculated	Actual
NEm-P = $\frac{668}{0.30}$ = 2227 lbs.		
NEg-P = $\frac{331}{0.18}$ = 1839 lbs.	4066	4480
NEm-Q = $\frac{317}{0.84}$ = 377 lbs.		
NEg-Q = $\frac{313}{0.51}$ = 613 lbs.	990	1012

TMT-6, using associative divisor.

NEm-P = $\frac{668}{0.28}$ = 2386 lbs.		
NEG-P = $\frac{331}{0.22}$ = 1505 lbs.	3891	4480

TMT-7

NEm-P = $\frac{666}{0.27}$ = 2467 lbs.		
NEg-P = $\frac{330}{0.18}$ = 1833 lbs.	4300	4592
NEm-Q = $\frac{320}{0.84}$ = 381 lbs.		
NEg-Q = $\frac{296}{0.51}$ = 580 lbs.	961	1018

TMT-7, using associative divisor.

No associative interaction in either phase; hence, no calculation by this method.

	Total lbs./phase Calculated	Total lbs./phase Actual
TMT-8		
$NEm\text{-}P = \frac{839}{0.27} = 3017$ lbs.		
$NEg\text{-}P = \frac{456}{0.18} = 2533$ lbs.	5550	5645
$NEm\text{-}Q = \frac{160}{0.84} = 190$ lbs.		
$NEg\text{-}Q = \frac{136}{0.51} = 267$ lbs.	457	470
TMT-8, using associative divisor.		

No associative interaction in either phase; hence, no calculation by this method.

	Calculated	Actual
TMT-11		
$NEm\text{-}P = \frac{696}{0.41} = 1698$ lbs.		
$NEg\text{-}P = \frac{444}{0.25} = 1776$ lbs.	3474	3766
$NEm\text{-}Q = \frac{330}{0.84} = 393$ lbs.		
$NEg\text{-}Q = \frac{284}{0.51} = 557$ lbs.	950	1023
TMT-11, using associative divisor.		
$NEm\text{-}P = \frac{698}{0.38} = 1832$ lbs.		
$NEg\text{-}P = \frac{444}{0.30} = 1480$ lb.s	3312	3766

TMT-12

	Total Lbs./Phase Calculated	Actual
$NEm\text{-}P = \frac{701}{0.41} = 1710$ lbs.		
$NEg\text{-}P = \frac{482}{0.25} = 1928$ lbs.	3638	4018
$NEm\text{-}Q = \frac{340}{0.84} = 405$ lbs.		
$NEg\text{-}Q = \frac{289}{0.51} = 507$ lbs.	972	1040

TMT-12, using associative divisor.

	Calculated	Actual
$NEm\text{-}P = \frac{701}{0.38} = 1845$ lbs.		
$NEg\text{-}P = \frac{482}{0.29} = 1662$ lbs.	3507	4018

See Table 3 for a summary of calculated and actual.

TABLE 3. Pounds of Ration Required - Calculated versus Actual Observed.

	Pounds of Feed Calculated Using Wt. % Divisor		Assoc. Divisor	Lbs. of Feed Actual Consumption	
TMT	Phase-P	Phase-Q	Phase-P	Phase-P	Phase-Q
1	3566	972	3454	4200	1007
4	3846	1000	3616	4270	1040
5	3903	999	3576	4466	1012
6	4066	990	3891	4480	1012
7	4300	961	na*	4592	1018
8	5550	457	na	4645	470
11	3474	950	3312	3776	1023
12	3638	972	3507	4018	1040

*Not applicable

CHAPTER VI

COMPUTATIONAL FORMAT OF H-72-KB-3 APPLIED TO TWO MORE STUDIES

In order to provide a larger testing base for the application of formulas (A), (B), (C) and (D), two other studies were subjected to the calculations carried out in detail for H-72-KB-3. These studies include H-72-KB-6 (1969-70) and H-72-KB-6 (1970-71). The methods of calculation are now clear and, hence, these studies will be presented in tabular form as shown in Tables 4-9.

TABLE 4. Consumption Data, H-72-KB-6 (1969-70)

	Phase-P				Phase-Q			
TMT	Days	CS[1]	GSC[2]	CSM[3]	Days	ALF[4]	GSC	CSM
1	140	25.8*	5.5	0.0	22	4.0	12.0	1.5
2	140	22.0	5.5	0.0	25	4.0	11.6	1.4
3	140	21.3	5.5	0.0	25	4.0	12.4	1.6
4	140	24.5	5.5	0.0	20	4.0	12.0	1.5
5	140	26.7	5.0	0.5	20	4.0	12.4	1.6
6	140	26.7	4.4	1.2	30	4.0	12.0	1.5
7	140	27.1	5.3	0.0	24	4.0	11.6	1.4
8	140	33.4	0.9	0.9	26	4.0	12.0	1.5
10	140	10.3	10.3	1.3	10	4.0	12.0	1.5

[1]CS = urea-limestone corn silage.

[2]GSC = ground shelled corn.

[3]CSM = cottonseed meal.

[4]ALF = alfalfa.

*Values in pounds as obtained from original study.

TABLE 5. Variables and Calculated Megacalories Required per Phase H-72-KB-6 (1969-70)

TMT	Phase-P					Phase-Q				
	g	Wo	T[1]	NEm[2]	NEg[3]	g[1]	Wo[1]	T	NEm	NEg
1	0.82*	238	140	766	542	0.80	352	22	143	98
2	0.83	236	140	763	547	0.75	352	25	163	104
3	0.82	233	140	764	541	0.84	348	25	157	114
4	0.85	234	140	767	581	0.73	353	20	130	80
5	0.91	235	140	765	611	0.79	362	20	132	90
6	0.87	235	140	776	588	0.70	357	30	194	131
7	0.84	235	140	761	554	0.71	353	24	153	92
8	0.78	237	140	753	503	0.84	346	26	164	119
10	0.91	235	140	765	611	0.90	362	10	65	51

[1] T = time in days

[2] Expressed in megacalories.

[3] NEg values are expressed in megacalories and computed with the formula for heifers.

* All weight values expressed in kilograms.

TABLE 6. Pounds of Ration Required - Calculated versus Actual Observed, H-72-KB-6 (1969-70)

	Pounds of Feed Calculated Using			Lbs. of Feed Actual Consumption	
	Wt. % Divisor		Assoc. Divisor		
TMT	Phase-P	Phase-Q	Phase-P	Phase-P	Phase-Q
1	4019	364	3624	4382	385
2	3965	407	3470	3850	425
3	3823	411	3410	3752	445
4	4153	314	3734	4200	350
5	4363	339	4050	4508	360
6	4342	491	3950	4522	525
7	4082	371	3634	4564	408
8	5076	430	4217	4928	455
10	2810	178	2817	3066	175

TABLE 7. Consumption Data, H-72-KB-6 (1970-71)

	Phase-P				Phase-Q			
TMT	Days	CS[1]	GSC[2]	CSM[3]	Days	ALF[4]	GSC	CSM
1	110	26.6*	6.0	0.0	53	3.0	12.2	1.5
2	110	28.8	5.4	0.6	48	3.0	12.4	1.5
3	110	26.6	5.9	0.0	55	3.0	11.5	1.4
4	110	29.2	4.8	1.3	48	3.0	11.5	1.4
5	110	26.8	5.8	0.0	55	3.0	11.9	1.5

[1]CS = urea-limestone corn silage.

[2]GSC = ground shelled corn.

[3]CSM = cottonseed meal.

[4]ALF = alfalfa.

*Values in pounds as obtained from original study.

TABLE 8. Variables and Calculated Megacalories Required per Phase H-72-KB-6 (1970-71)

TMT	Phase-P g	Wo	T[1]	NEm[2]	NEg[3]	Phase-Q g_1	Wof	T	NEm	NEg
1	0.82*	221	110	559	624	0.94	311	53	323	268
2	0.94	222	110	569	471	0.84	325	48	291	212
3	0.87	218	110	564	427	0.94	314	55	339	281
4	0.92	222	110	568	460	0.71	323	48	292	175
5	0.85	222	110	568	419	0.88	316	55	333	256

[1]T = time in days.

[2]Expressed in megacalories.

[3]Neg values are expressed in megacalories and computed with the formula for heifers.

*All weight values expressed in kilograms.

TABLE 9. Pounds of Ration Required - Calculated versus Actual Observed, H-72-KB-6 (1970-71)

	Pounds of Feed Calculated Using			Lbs. of Feed Actual Consumption	
	Wt. % Divisor		Assoc. Divisor		
TMT	Phase-P	Phase-Q	Phase-P	Phase-P	Phase-Q
1	2921	886	2636	3586	885
2	3343	742	3067	3828	811
3	3052	944	2636	3586	875
4	3312	685	3081	3883	763
5	3032	875	2636	3608	902

CHAPTER VII

RESULTS AND DISCUSSION

Statistical Results

All of the studies were analyzed using regression to determine the probability that the calculated, predicted consumption approximated the actual, observed consumption. The studies are broken into phases for analysis. Phase-P in each study compares the observed consumption with the consumption calculated using both methods of obtaining the divisor in equations (20) and (21). Phase-Q in each study compares the observed consumption with the consumption calculated using only the weighted percent method of obtaining the divisor in equations (22) and (23). The important results of the analysis including; 95 percent confidence limits, F, probability of F, standard deviation and standard deviation as a percent of Y - mean are presented in Tables 10-18.

TABLE 10. Regression Analysis for Y versus X[1], Phase-P H-72-KB-3

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. ≥ F	Std Dev	Std Dev As % $\bar{Y}$
						15.58	0.016	138.4	3.29
1	3566	4200	3792	4211	in				
4	3846	4270	4131	4478	in				
5	3903	4466	4170	4563	in				
6	4066	4480	4255	4831	in				
7	4300	4592	4349	5245	in				
8	5550	5645	4769	7530	in				
11	3474	3766	3641	4164	in				
12	3638	4018	3901	4258	in				

[1]Where X represents the calculated value by weighted percent divisor.

TABLE 11. Regression Analysis for Y versus X^1[1], Phase-P H-72-KB-3

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\bar{Y}$
						8.20	0.046	175.4	4.18
1	3454	4200	3847	4309	in				
4	3616	4270	4057	4474	in				
5	3576	4466	4020	4419	out				
6	3891	4480	4162	5006	in				
7	na[2]	4592	4001	4398	out				
8	na	5645	4001	4398	out				
11	3316	3766	3572	4255	in				
12	3507	4018	3932	4347	in				

[1] Where X^1 represents the calculated value by associative divisor.

[2] Not applicable - independent variables missing, predicted value based on mean value for missing independents.

TABLE 12. Regression Analysis for Y versus X^1, Phase-Q H-72-KB-3

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\bar{Y}$
						534.1	0.0001	22.31	2.34
1	972	1007	996	1037	in				
4	1000	1040	1025	1067	in				
5	999	1012	1023	1066	out				
6	990	1023	1015	1057	in				
7	961	1018	985	1025	in				
8	457	470	420	528	in				
11	950	1023	973	1013	out				
12	972	1040	996	1037	out				

[1]Where X represents the calculated value by weighted percent divisor.

TABLE 13. Regression Analysis for Y versus X[1], Phase-P H-72-KB-6 (1969-70)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Sdt Dev	Std Dev As % $\overline{Y}$
						45.25	0.0003	218.9	5.22
1	4019	4382	3980	4326	out				
2	3965	3850	3931	4282	in				
3	3823	3752	3794	4171	out				
4	4153	4200	4095	4444	in				
5	4363	4508	4258	4647	in				
6	4342	4522	4243	4625	in				
7	4082	4564	4035	4380	out				
8	5076	4928	4720	5426	in				
10	2801	3066	2669	3518	in				

[1]Where X represents the calculated value by weighted percent divisor.

TABLE 14. Regression Analysis for Y versus X^1 [1], Phase-P H-72-KB-6 (1969-70)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. > F	Std Dev	Std Dev As % Y
						53.67	0.0003	203.1	4.84
1	3624	4382	3995	4316	out				
2	3470	3850	3782	4137	in				
3	3410	3752	3694	4073	in				
4	3734	4200	4133	4459	in				
5	4050	4508	4471	4927	in				
6	3850	4522	4371	4772	in				
7	3634	4564	4008	4329	out				
8	4217	4928	4631	5192	in				
10	2817	3066	2747	3508	in				

[1] Where X^1 represents the calculated value by associative divisor.

TABLE 15. Regression Analysis for Y versus X[1], Phase-Q H-72-KB-6 (1969-70)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\overline{Y}$
						760.4	0.0001	9.93	2.53
1	364	385	380	396	in				
2	407	425	427	444	out				
3	411	445	431	449	in				
4	314	350	324	343	out				
5	339	360	353	369	in				
6	491	525	514	542	in				
7	371	408	388	404	out				
8	430	455	451	471	in				
10	178	175	165	203	in				

[1] Where X represents the calculated value by weighted percent divisor.

TABLE 16. Regression Analysis for Y versus X[1], Phase-P H-72-KB-6 (1970-71)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\bar{Y}$
						27.26	0.0137	52.78	1.43
11	2921	3586	3420	3663	in				
12	3343	3828	3733	3976	in				
13	3052	3586	3555	3722	in				
14	3312	3883	3721	3943	in				
15	3032	3608	3536	3711	in				

[1]Where X represents the calculated value by weighted percent divisor.

TABLE 17. Regression Analysis for Y versus X^{1} [1], Phase-P H-72-KB-6 (1970-71)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	Y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\bar{Y}$
						176.5	0.0009	21.67	0.59
11	2636	3586	3553	3633	in				
12	3067	3828	3804	3899	in				
13	2636	3586	3553	3633	in				
14	3081	3883	3811	3910	in				
15	2636	3608	3553	3633	in				

[1] Where X^{1} represents the calculated value by associative divisor.

TABLE 18. Regression Analysis for Y versus X[1], Phase-Q H-72-KB-6 (1970-71)

	Calculated Value	Observed Value	Lower 95% CL For Mean	Upper 95% CL For Mean	y in /out	F Value	Prob. >F	Std Dev	Std Dev As % $\bar{Y}$
						15.79	0.028	26.91	3.18
11	886	885	831	922	in				
12	742	811	755	856	in				
13	944	875	845	966	in				
14	685	763	709	845	in				
15	875	902	828	914	in				

[1]Where X represents the calculated value by weighted percent divisor.

Discussion and Conclusions

Formulas (A), (B), (C) and (D) have been derived and then tested for practical application. The formulas, as an entity, were mathematically rigorous and require no further proof of reliability in computing total energy in multiphase feeding regimes. They were tested indirectly for their practical value after methods were applied to yield projected consumption as a comparative figure.

Statistical analysis of the results in terms of calculated versus observed consumption indicated that this method of predicting consumption was dependable at very low probability levels.

The statistics for consumption by the weighted percent method were slightly better than those by the associative method, but none in any phase of any treatment were outside the 5% level for the probability of F. This slight difference may be due to the fact that the percent corn in the silages was estimated in the associative calculation of ration net energy. It was interesting that calculation of ration energy by the simple weighted average was as accurate here as the complicated formulas for associative calculation.

The advantage of this method is that only four simple formulas can be used to determine the projected net energy required in multiphase feeding regimes. If an individual feeder wanted to know how much feed to produce or purchase to meet the requirements for energy of a projected feeding regime, he would simply substitute into the variables the values which would meet the treatment he planned to employ. Knowing the projected energy requirement, he could calculate the projected consumption by dividing by the net energy of the ration computed by simple weighted averages of the individual feeds. The only values he would have to look up would be those for the net energy of the feeds. Multiplying this average projected consumption by the number of animals he planned to finish, the amount of feed to be purchased or produced could be obtained.

In summary, then, this method allows for the simple calculation of the projected net energy requirements and subsequently the total projected consumption in single and multiphase feeding programs.

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