Determination of net energy of unitan barley and prediction of gains of steers using net energy values
by Olaf Benjamin Sherwood

A thesis submitted to the Graduate Faculty in partial fulfillment of the Requirements for the degree of
MASTER OF SCIENCE in Animal Science
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Abstract:
The net energy system of evaluating feeds was studied to determine the net energy value of Unitan barley (test wt of .605 kg/liter and 9.9% C.P.) for maintenance and production and to evaluate established net energy values for wintering and fattening cattle, In Trial I, 36 weaned steer calves averaging 214.62 kg were stratified by weight, breed of dam and sire into nine groups of four head each. One lot of four steers was slaughtered initially to establish initial body composition. The remaining 32 individually fed steers were randomly assigned to treatments replicated once as follows: basal ration (80% grass hay and 20% soybean oil meal) for maintenance, basal plus barley for maintenance, intermediate and large gain. All steers were slaughtered at the conclusion of the trial to determine energy retention. Heat production at zero feed intake was measured by the regression analysis' of daily heat production per Wkg^0.75 on daily metabolizable energy intake per Wkg^0.75 and was found to equal 70 kcal per Wkg^0.75 per day. A regression of heat production on metabolizable energy intake showed that the NEm value of barley was 1.81 Meal per kg of dry matter. The average NEp of barley as determined by the difference trial was 1.145 Mcal per kg of dry matter.

In Trial II, 44 weaned steer calves, initially weighing 243.13 kg were fed a wintering ration for 84 days. Steers were stratified by weight and source and were randomly allotted to four lots of 8 head each fed outside and two lots of 6 head each fed inside. Each lot received either a 65 or 50% roughage ration, based on established net energy values for the feeds and requirements of the steers, initially calculated for an expected gain of 0.68 kg per day. Rations were recalculated at the end of the trial, based on average daily feed consumed, and the expected gain was changed to 0.64 kg per day. Actual gains varied from 0.64 to 0.82 kg per day. The "t" test for paired observations indicated a significant difference ($P<0.025$) between the actual and expected gain during the wintering period.

Steers used in Trial II were used in Trial III for a fattening period of 70 days, All steers were implanted with 36 mg Stilbestrol, Each lot received either a 15 or 5% roughage ration. Rations were calculated for a 1.13 kg gain per day. When the average ration was recalculated at the end of the trial, the expected gains ranged from 1.03 to 1.10 kg. The actual gains ranged from 1.17 to 1.39 kg per day with the actual gain being greater than expected. The "t" test for paired observations indicated a highly significant difference ($P<0.01$) between the actual and expected gain during the fattening period.

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Date August 5, 1970

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A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

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ABSTRACT

The net energy system of evaluating feeds was studied to determine the net energy value of Unitan barley (test wt of .605 kg/liter and 9.9% C.P.) for maintenance and production and to evaluate established net energy values for wintering and fattening cattle.

In Trial I, 36 weaned steer calves averaging 214.62 kg were stratified by weight, breed of dam and sire into nine groups of four head each. One lot of four steers was slaughtered initially to establish initial body composition. The remaining 32 individually fed steers were randomly assigned to treatments replicated once as follows: basal ration (80% grass hay and 20% soybean oil meal) for maintenance, basal plus barley for maintenance, intermediate and large gain. All steers were slaughtered at the conclusion of the trial to determine energy retention. Heat production at zero feed intake was measured by the regression analysis of daily heat production per $W_{kg}^{0.75}$ on daily metabolizable energy intake per $W_{kg}^{0.75}$ and was found to equal 70 kcal per $W_{kg}^{0.75}$ per day. A regression of heat production on metabolizable energy intake showed that the NE_m value of barley was 1.81 Mcal per kg of dry matter. The average NE_p of barley as determined by the difference trial was 1.145 Mcal per kg of dry matter.

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INTRODUCTION

Cattle production in Montana is of prime importance to the economy of the State. The number of cattle on feed in Montana has increased each year, suggesting an increasing interest in finishing cattle. An abundance of feed grain is grown in Montana which can be used to produce finished beef.

Animal nutrition is concerned with the development and application of scientific knowledge to the day-to-day feeding of livestock. Nutrient requirements of beef cattle are dependent upon the level of production, size and type of cattle being fed. Most producers today recognize the fact that all nutrients are interrelated. Because energy and protein requirements are large in terms of amount and cost in cattle feeding, modern recommendations suggest that all other nutrients be fed at a level to make good utilization of the energy while being adequate in protein.

In November 1958, the NRC Committee on Animal Nutrition passed a resolution to start using the caloric system, along with the total digestible nutrient (TDN) system, to describe the energy values of feeds, rations and nutrient requirements of animals. In 1970, the revision of the National Research Council requirements for beef cattle was extensive. Not only were the requirements given in kilograms of body weight; but nutrient requirements were given in terms of dry matter and the new energy values, NE_m and NE_p, developed by Lofgreen and co-workers, were given for growing and finishing beef cattle. Before the caloric

system can be used effectively throughout the United States, it will be necessary to evaluate feeds on the basis of net energy in various areas due to environmental and feed differences.

Because barley is the principal feed grain in Montana, it is necessary that it be evaluated on the basis of net energy for growing and finishing cattle under Montana conditions.

REVIEW OF LITERATURE

The Caloric System

Energy may be defined as "That which gives rise to changes in the properties of bodies and the power to produce such changes" (Armsby, 1917). According to Crampton and Harris (1969), the fractions of biological energy are determined by measuring only the potential energy of the food ingested by an animal, the fecal recovery, the urinary recovery, the methane-gas recovery (using the calorimeter or by a formula for ruminants) and the increased heat loss in the fed animals over that of the animal while fasting, i.e. the heat increment (HI).

From this, it is assumed that digestible energy (DE) = food energy minus total energy in feces; metabolized energy (ME) = DE minus total energy in urine (and the methane energy for ruminants); and net energy (NE) = ME minus the total heat increment (HI). In other words, the DE, ME and NE values of a food are conventionally obtained by difference.

Figure 1 shows the conventional biological partition of food energy (Crampton and Harris, 1969).

The largest purpose which food serves is the production of energy for body processes. Because all organic nutrients can serve this purpose, energy value provides a common basis for expressing their nutritive value (Maynard and Loosli, 1962).

Energy Terms

In order to fully understand the caloric system of describing energy values, it is essential to have a knowledge of energy terms.

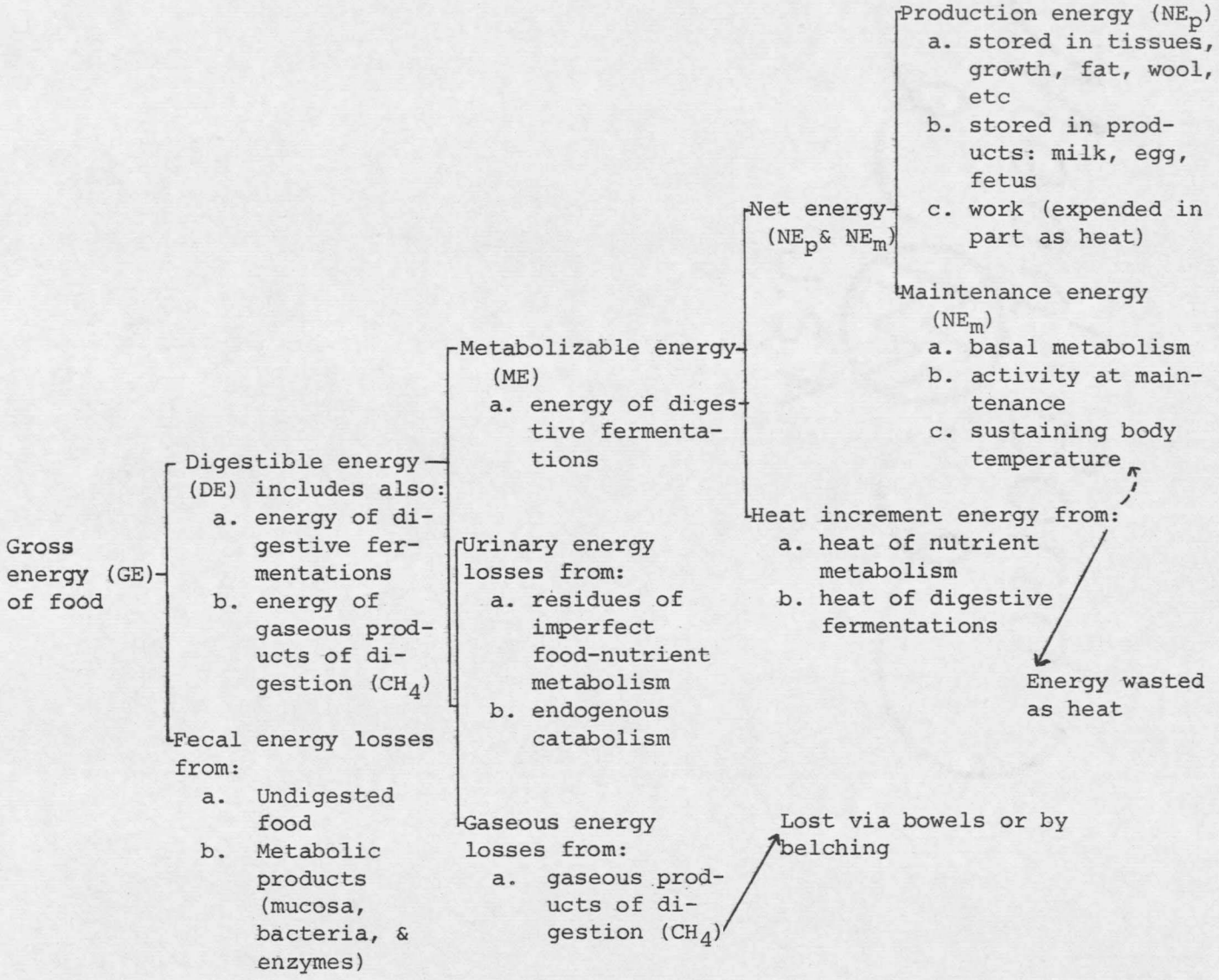

FIGURE 1. CONVENTIONAL BIOLOGICAL PARTITION OF FOOD ENERGY.

The following are those terms suggested by Crampton and Harris (1969).

Calorie (cal). A small calorie is the amount of heat required to raise the temperature of one gram of water to 15.5 from 14.5 degrees centigrade.

Kilocalorie (kcal). A kilocalorie is 1,000 small calories.

Megacalorie (Mcal). A megacalorie is equivalent to 1,000 kilocalories or 1,000,000 calories.

Gross Energy (GE). GE is the amount of heat, measured in calories, that is released when a substance is completely oxidized in a bomb calorimeter containing 25 to 30 atmospheres of oxygen.

Metabolic Body Size ($W_{kg}^{0.75}$). Metabolic size is defined as the weight of the animal (in kg) raised to the three-fourths power. Metabolic body size can also be expressed in pounds.

Net Energy (NE). NE = ME - HI. It includes the amounts of energy used either for maintenance only or for maintenance plus production. Net energy can also be expressed as the gross energy (GE) of the gain in tissue and/or the products synthesized, plus energy required for maintenance. Below the critical temperature some of the HI is also a part of net energy.

There are three expressions of net energy (NE) (Lofgreen and Garrett, 1967) which are commonly used and extremely important to understand when referring to a discussion of NE: (1) net energy for

maintenance alone (NE_p), (2) net energy for production above maintenance (NE_m) and (3) net energy for maintenance plus production (NE_{m+p}).

NE_m is defined as that amount of energy which is equal to the heat produced by a fasting animal. The amount of feed required to just maintain an animal in energy balance will have an NE_m value equal to that amount of heat which would have been produced at no feed intake.

NE_p is defined as the energy stored in new body protein and fat brought about by addition of feed above the maintenance requirement. This stored energy is measured by a "difference trial" which measured the increase in energy gained by the animal due to an increase of feed intake above maintenance.

NE_{m+p} is defined as that energy required for both maintenance and production.

Development of Net Energy Values

In connection with his work with the respiration calorimeter, Armsby developed the net energy system of evaluating feeds founded upon a concept not much different from the starch values of Kellner (Maynard and Loosli, 1962). Kellner appears to have been the first to attempt any practical application of the conception of the feed as a source of energy to the body and he developed the so-called starch values (Armsby and Fries, 1915). Kellner (1913) expressed the fat-forming value of feeding stuffs, using starch as a standard.

It became accepted as a fundamental doctrine in animal nutrition that the prime function of food is to supply energy for the operation of the animal body and that all its other diverse uses are essentially tributary to its main purpose. Armsby and Fries (1918a) determined experimentally how much energy the various feed stuffs can actually contribute toward the upkeep of the animal body.

Armsby and Fries (1915) felt that the losses of feed energy from the animal were of two classes: (1) losses of unused chemical energy in the feces, urine and methane and (2) losses in the form of heat due to the increased metabolism solely due to the ingestion of feed. The remainder of the chemical energy in the feed was designated as the net energy value for maintenance plus production. In their work with the respiration calorimeter, Armsby and Fries (1915) found that animals required more energy when standing than animals which were lying down.

In the determination of net energy values, Armsby measured the heat resulting from the ingestion of a given amount of feed increased the intake, and obtained by difference the heat increment corresponding to the amount by which the feed intake was increased. He then subtracted the heat increment from the metabolizable energy of the same intake to obtain the net energy value (Maynard and Loosli, 1962).

Kriss (1925) developed and used a new method which involved the separate determination (1) of the net energy required for maintenance

(2) of the gain of energy by the animal and (3) of the heat increment value of the feed. Considerable work has been done in the past years on the net energy values of feed stuffs and the requirements of animals. In about 1955, California scientists became interested in investigating the net energy value of feeds and the requirements of steers and heifers for finishing. The system for expressing net energy requirements and feed values for evaluating livestock rations as developed in California is a more precise method of predicting performance of feedlot rations than feeding standards using Total Digestible Nutrients (Lofgreen and Garrett, 1968). On the basis of their initial work, California workers quantitated net energy (NE) requirements of growing-finishing cattle and developed a system which, although first proposed over a hundred years ago, is becoming more widely used in the U. S.

Lofgreen and Garrett (1968b) reported that in order to measure the NE_m requirement it is necessary to know the heat production of the fasting animal since this amount of net energy must be furnished to the animal to keep it in energy equilibrium. The heat production of the fasting animal has been considered to be equal to basal metabolism which is often expressed as $70W^{0.75}_{kg}$ with heat production expressed in kcal and W is bodyweight in kg. It is possible to indirectly measure heat production (HP) at zero feed intake by deducting energy balance (EB)

from metabolizable energy intake (ME) thus

$$HP = ME - EB.$$

The energy retained in the animal body is determined by a comparative slaughter method. In fed animals, HP is made up of basal metabolism, heat increment and heat produced by activity. At zero feed intake the heat increment is also zero and the components of HP are basal metabolism and heat activity which can be considered to be equal to the net energy required for maintenance or NE_m. It is possible to estimate HP at zero feed intake if HP is measured at various levels of feed intake.

Lofgreen and Garrett (1968b) indicated that the heat production of fasting animals was between 72 and 82 kcal per $W_{kg}^{0.75}$ with the mean value being 77 kcal. The average NE_m requirement can be considered to be equal to 77 kcal per $W_{kg}^{0.75}$. The NE_m requirement can be expressed

$$NE_m = 0.077W_{kg}^{0.75}$$

where NE_m is in Mcal per day and W is bodyweight in kg. It has been found that the heat produced by steers and heifers is not different and thus the energy requirement for maintenance per unit of $W_{kg}^{0.75}$ is the same which is equal to 0.077 Mcal per $W_{kg}^{0.75}$.

Garrett, Meyer and Lofgreen (1959) expressed maintenance requirement of sheep as $33W^{0.75}$ and cattle as $38W^{0.75}$ or a combined species requirement of $35W^{0.75}$ where the values are calculated in kilocalories

per day when W is in pounds. Reasonable estimates of the requirement to maintain energy equilibrium, in terms of the different measures of food energy, can be made from the following relationships:

$$TDN = 0.036W^{0.75}$$

$$DE = 76W^{0.75}$$

$$ME = 62W^{0.75}$$

$$NE = 35W^{0.75}$$

W is in pounds, TDN in pounds per day; and De, ME and NE are in kilocalories per day.

Lofgreen and Garrett (1968b), in the determination of NE_m values of the ration, have shown that the quantity of feed intake per unit of $W_{kg}^{0.75}$ required to maintain an animal in energy equilibrium will have a NE_m equal to the heat produced at no feed intake or 0.077 Mcal. The feed intake required to maintain energy equilibrium can be measured rather easily from the relationship of heat produced to metabolizable energy intake.

The determination of NE_p requirements for weight gain is simply the energy deposited in the gain. This is measured by what the nutritionists call a "difference trial". Such a trial measures the increase in energy gained due to an increase in the amount of feed intake above maintenance. In a difference trial, the lower level of feed is fed to maintain energy equilibrium and the higher level of feed intake is free choice. Lofgreen and Garrett (1967) directly determined the NE_p

requirement for production of weight gain by the energy deposited per unit of gain.

It has been shown by Lofgreen and Garrett (1968b) that for any size of animal the energy stored in the weight gain or the NE_p requirement can be expressed

for steers

$$NE_p = (52.72g + 6.84g^2)\ (W^{0.75})$$

for heifers

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

Where NE_p is in kcal, g is daily gain in kg and W is body weight in kg.

The NE_p value of a ration as found by Lofgreen and Garrett (1968) is equal to the energy deposited in the body weight gain brought about by feeding the particular feed in question. This gain or difference is determined by the difference trial. It has been found that any two levels of feed above the maintenance requirement can be used in a difference trial but a large difference will result in a more accurate estimate of the NE_p value of the ration.

The partial efficiency of energy utilization for maintenance is higher than it is for production (Kleiber, 1961; Preston and Hembry, 1969). The net energy of a feed will then vary with the level of feeding, being higher at low levels of feeding and decreasing as feed intake increases. It is obvious, therefore, that a system based upon net energy must take this into consideration by listing separate net

energy values for different physiological functions, such as net energy for maintenance and/or net energy for production. Studies (Lofgreen, Bath and Strong, 1963; Garrett, Lofgreen and Meyer, 1964) have shown that, from maintenance to ad libitum feed consumption, the partial net energy of a feed used for weight gain does not deviate significantly from linearity. This means that the partial net energy of a feed, when utilized for weight gain above maintenance, can be considered to be constant. The net energy for maintenance of that quantity of feed needed to maintain energy equilibrium is equal to the heat produced by a fasting animal. The partial net energy of feeds for maintenance (NE_m) and the partial net energy for production of weight gain (NE_p), therefore, are more nearly constant than is the total net energy of a feed for both maintenance and production (NE_{m+p}), the latter being a weighted average of the NE_m and NE_p depending upon the level of feeding. It seems logical that a net energy system based upon the use of separate expressions, NE_m and NE_p, would be more useful and accurate than one based upon NE_{m+p} which is known to vary with feeding level.

In the determination of total net energy values of feeds for beef cattle, it is necessary to have some measure of the energy retention brought about by the consumption of a given quantity of feed. Armsby and Fries (1915) measured this by use of a respiration calorimeter. To overcome the disadvantages of respiration trials, Lofgreen and Garrett (1968b) developed a system of using body weight gains as measures of

energy retention. Lofgreen (1964) at the California Agricultural Experiment Station developed a comparative slaughter technique to measure energy retention.

Animals used in such a study are accustomed to the environment and placed on the same ration to give a uniform fill for a minimum of 10 days. An initial live weight measurement is made and randomly selected group is slaughtered to represent the initial body composition (Lofgreen, 1964). The estimation of the initial slaughter group is applied to the remainder of the cattle. At the conclusion of the trial, the remaining cattle are slaughtered to determine energy retention. This method is described in detail in a review by Lofgreen (1964). The specific gravity of carcasses is measured and the body fat and protein determined for energy retention.

In determining net energy values, it is also necessary to know the empty body weight. Through a series of trials involving the weighing of the full reticulum and rumen of slaughtered cattle which had a 12-hour shrink, Lofgreen and Hull (1962) developed an equation to estimate the empty body weight. A regression analysis of the data revealed that the empty body weight of beef cattle can be accurately predicted from the warm carcass weight taken at slaughter. The equation, $Y = 70 + 1.45X$ describes this relationship where Y is the empty body weight in pounds and X is the warm carcass weight in pounds.

Uses Of The Net Energy System

The system of determining net energy feed values and animal requirements as developed by Lofgreen and Garrett (1967) is often referred to as the California Net Energy System. Any system of expressing energy requirements and feed values must lend itselt to use in feeding livestock.

The three most practical uses of the net energy system are as follows (Lofgreen, 1970a; Lofgreen and Garrett, 1967; Lofgreen and Garrett, 1968a; Lofgreen and Garrett, 1968b; NRC, 1970):

1) The system must lend itself to ration formulation in which case information is needed on the expected feed consumption of the kind of cattle being finished and the rate of gain they are expected to make.

2) A second use of the net energy system is in the calculation of the quantity of feed required to produce a desired rate of gain.

3) A third, and perhaps the most useful method of application of this system, is in evaluating a given feeding program. Using this system, it is possible to evaluate the observed performance of animals in comparison to that expected from their feed consumption.

This system, at present, is limited to use with growing and finsihing cattle; the principles can be extended to other psyciological functions such as gestation, lactation, work, etc. These applications await further research to make them more useful.

Feeding Experiments To Determine NE

A number of workers have used the difference trial and the comparative slaughter technique to determine NE values of feed stuffs and also the NE requirements of growing and finishing cattle.

Hintz, Hansen and Garrett (1969), using rolled whole barley and a ration made up of the high fiber fraction of the barley, found that there was a trend for increased amounts of the high fiber fraction ration to be required for weight and energy gain. The calculated net energy values were lower for the high fiber fraction ration and indicated that this fraction of barley had about 94% of the value of the entire barley kernel in terms of NE_p.

Garrett (1965) compared steam rolled or ground barley to steam rolled or ground milo for feedlot cattle. Using the comparative slaughter technique, the average values of NE_p were found to be 1.31 and 1.43 Mcal per kg for barley and milo. There was no significant difference between the values for steam rolled or ground grain.

Garrett et al. (1964) determined the average net energy values (NE_p) of barley, milo and a 50:50 mixture to be 56 ± 4, 59 ± 4, 59 ± 4 Mcal/100 lb. of dry matter. These averages indicated that these grains were about equal to their net energy values.

Lofgreen and Christensen (1962) reported that barley straw had a NE value of approximately 23 Mcal/100 lbs. which is not different than the ENE given by Morrison (1959). The average value of 44.4 Mcal of

NE/100 lb. of alfalfa is somewhat higher than the value of 40.6 listed by Morrison. Feeding straw as half of the roughage resulted in lowered gains and lowered energy content of the gain.

The net energy of successive increment (NE_p) of alfalfa hay and of a high concentrate ration has been determined with growing-fattening beef heifers (Lofgreen, et al., 1963). These workers found that the first increment of alfalfa from maintenance to approximately one-half maximum gain had a NE_p for energy retention of 30.1 Mcal/100 lb. The second increment, increasing consumption to full feeding, had a NE_p of 25.1 Mcal/100 lb. The corresponding values of a high concentrate ration were 54.8 and 59.9 Mcal/100 lb. For maintenance, alfalfa had a relative NE_m value of 67% of that of the high concentrate while for gain alone the value of alfalfa was only 49% that of the high concentrate.

Irvin et al. (1951) found that production on an all alfalfa hay ration was much closer to that expected on the basis of net energy calculations than that expected on the basis of TDN calculations.

Conrad et al. (1966) reported that raising the level of roughage from 10 to 30% decreased the rate of gain. The NE_p values of hays also declines with advancing maturity (Welch, et al., 1969).

Fox et al. (1970) using the comparative slaughter technique found that the NE_{m+p} intake was significantly higher for corn grain rations than for corn silage, sorghum silage or sorghum grain rations ($P<0.05$). Both the corn rations had higher NE_{m+p} values per kg of dry matter than

did either of the bird resistant sorghum rations. The corn silage ration had the highest NE_{m+p} (1.40 Mcal/kg DM) followed by corn grain, (1.29 Mcal/kg DM), bird resistant sorghum silage, (0.95 Mcal/kg DM) and bird resistant sorghum grain (0.94 Mcal/kg DM).

Hall et al. (1966) reported that the level of intake above maintenance did not significantly affect the NE_p values of corn or milo and that there were no significant differences observed in net energy between corn and milo at any level of feed intake.

It was found by Hall et al. (1968) that corn and sorghum grain did not differ significantly in net energy values.

Lofgreen, Bath and Young (1962) determined the net energy of various kinds of beet pulp using barley as a reference standard. The value used for barley was 61.5 Mcal/100 lb. of dry matter. Using the barley as a standard the NE of plain beet pulp fed at 24% of the ration was 51.1 Mcal/100 lb. DM. Beet pulp containing 28% CSF solids contained 45.7 and 59.0 Mcal NE/100 lbs. DM when fed at a level of 24 and 48% of the ration. The addition of molasses solids at the rate of 25% increased the NE to 56.6 and 60.5 Mcal when fed at 24 and 48% respectively. From this, it was found that plain, CSF and molasses pulps contains an average of 83, 79 and 95% as much NE as did the barley.

The NE_p of molasses at 5, 10 and 15% of a ration was 0.78 Mcal per kg and declined 0.70 Mcal per kg when molasses was increased to 20% of the ration. Those animals receiving the 20% molasses level required

more feed than the other group when adjusted to equal energy gain (Lofgreen, 1965).

Lofgreen and Otagaki (1960) found that feeding molasses at 10% of the ration significantly increased fat deposition while not increasing total gain over the basal ration. Molasses at higher rates lowered fat deposition. The NE of molasses fed at 10, 25 and 40% of the ration was 68.9, 37.8 and 35.1 Mcal/100 lb. respectively. Kroman (1967) found similar results except that the NE of molasses did not decrease as much.

Investigations have shown that the same feeds may have decidedly different net energy values for some classes of stock than for others (Morrison, 1937). It was found that the value of a ration for the fattening of cattle was only 76% as great as the net energy value for maintenance.

The net energy value of a feed decreases as the amount of feed exceeds maintenance (Morrison, 1937; Hall et al., 1968; Garrett et al., 1964; Lofgreen, et al., 1963 and Lofgreen, 1970a). Similar results were found with sheep (Kroman and Ray, 1967).

The losses of energy in urine and extent of the methane fermentation showed a distinct increase as the total amount of ration was reduced (Armsby and Fries, 1918b).

Higher NE_p values will be obtained from dairy cattle than from beef cattle fed the same rations (Bath et al., 1966). The mean NE values for beef cattle were 86% of that for dairy cattle.

Forbes et al. (1931) reported that the net energy value of a feeding stuff may differ as affected by the proportion of the ration which it constitutes. This finding tends to strengthen the theory that the determination of consistent net energy values would require the presence of all nutrients, except such as serve for energy production, in optimum quantities and proportions. Kleiber, Goss and Guilbert (1936) and Forbes et al. (1935) reported similar results.

Computed Gains Of Growing-Finishing Cattle

Very little experimental work has actually been done where the computed gains were compared to the actual gains of growing and finishing cattle. Keith and Everson (1967) individually fed 540 feeder cattle to study the adaptability of the net energy values of feeds, derived by Lofgreen et al. (1968b). It was found that steers fed from one to four parts of concentrate to one part of alfalfa hay had observed values approximately the same as the computed. Those steers fed a ration with high levels of alfalfa had lower computed values of gains than observed values. The differences between observed and computed values for gain was greater for steers than for heifers.

The system of NE_m and NE_p values of feed appears to be more accurate than the NE_{m+p} system according to research done by Keith and Everson (1969).

The NE values of feed stuffs and NE requirements of steers and heifers as expressed by Lofgreen et al., 1967; Lofgreen et al., 1968;

Lofgreen et al., 1968b; Gill, 1968; Lofgreen, 1970 and NRC, 1970, are values established with the use of stilbestrol. It must be remembered that these statements of requirements and feed values are averages and individual animals, lots of animals and feed will vary. On the average, they may be relatively accurate.

Stilbestrol is used quite frequently with growing and finishing cattle in feedlots today. Gill (1968) reported that when using the net energy system that 10% less gain is expected without stilbestrol on the same quantity and quality of feed. Adeyanju, Fowler and Burroughs (1969) found that stilbestrol stimulated feed consumption by about 5%, increased live weight gains by about 15% and lowered feed requirements per unit of live weight gain by about 10%. It was found that stilbestrol did not exert an appreciable influence upon ration energy available for metabolism.

Fowler et al. (1970) group-fed 12 pens of cattle six finishing rations at two levels of intake. The intake levels were (1) slightly above maintenance and (2) ad libitum feeding or levels of feeding equal to two to three times maintenance. The six finishing rations can be briefly described as two high-gain finishing rations, one with and one without stilbestrol; two whole-plant corn-silage (32% DM) rations, one with and one without stilbestrol; and two whole-plant corn-silage (45% DM) rations, one with and one without stilbestrol. These rations are identical to those used by Adeyanju et al. (1969).

The feedlot results showed that approximately 6% more feed was consumed in the three rations containing stilbestrol as compared with those containing no stilbestrol. This difference was significant at the 10% level of probability. Daily live weight gains were higher in steers fed corn rations. Live weight gains averaged 23% greater with the three rations containing stilbestrol as compared with the three control rations. Approximately 13% less feed per unit of live weight gain was required as a result of stilbestrol feeding.

The net energy values in terms of megacalories per kilogram of ration dry matter, when the ration was utilized for maintenance, were considered higher for the two grain rations (avg 252) as compared with the four silage rations (avg 178). Little difference existed between the rations with respect to net energy values utilized for fat gain or protein deposition. That the NE_p values for the corn rations were not higher than the silage rations may have been due to the ad libitum feeding conditions imposed. The NE_m requirements were estimated on the basis of .077 Mcal per $W_{kg}^{0.75}$.

As a result of feeding stilbestrol there was a reduction in net energy requirements of about 18% for maintenance and gain.

The results of this test and the test by Adeyanju et al. (1969) indicate that stilbestrol exerts its major nutritional influence upon improved protein utilization, accompanied by increased growth and the formation of more proteinaceous lean tissue in beef cattle.

Fowler et al. (1968) found similar results in that the net energy value for maintenance and production were higher for those rations containing stilbestrol.

Garrett (1965) fed steam rolled and ground barley or milo and found that the weight gains made by stilbestrol implanted cattle were significantly increased over the controls, but no effect of stilbestrol was indicated on the NE_p of the feed.

Environmental temperature can affect the NE necessary for maintenance and production. Weichenthal, Matsushima and Knox (1967) found that energy intake and heat production were depressed at high temperatures while at low temperatures the energy intake and heat production increases. Winchester (1964) reported similar results.

Continued study and refinement of the NE system will make it more useful not only for growing-finishing cattle but for other classes of livestock.

METHODS AND PROCEDURES

These experiments were conducted at the Montana Agricultural Experiment Station, Bozeman, Montana. Cattle used in the trials were produced at the U. S. Ranch Livestock Experiment Station, Miles City, Montana, Red Bluff Research Ranch, Montana Agricultural Experiment Station, Norris, Montana and Montana Agricultural Experiment Station, Bozeman, Montana. Before starting the experiments, all steers were vaccinated for Infectious Bovine Rhinotracheitis, Parainfluenza$_3$, Bovine Virus Diarrhea, Blackleg, Malignant Edema and Leptospirosis. All steers were treated with Ruelene by the back pour method for grub control. All steers used in Trial I were treated with Tramisol for lungworms, stomach and intestinal worms. The steers were allowed time to become accustomed to the lots before any phase of the trials started.

The data submitted in this manuscript are presented in the metric system. Appendix tables are presented in the English and metric system.

Trial I. Determination Of Net Energy Of Unitan Barley

Thirty-six weaned steer calves, Angus X Hereford, Hereford X Angus, Angus X Angus-Hereford and Angus X Hereford-Angus, produced at the U. S. Range Livestock Experiment Station at Miles City, Montana were used in Trial I. These calves were from two sires, one Hereford and one Angus.

The steers were stratified by weight, breed of dam and sire into nine groups of four head each. These groups were then randomly assigned

TABLE 1. EXPERIMENTAL DESIGN

Treatment	Ration	Predicted
I	Basal, X $W_{kg}^{0.75}$ a/	Maintenance
II	Basal, 1/2 X $W_{kg}^{0.75}$ plus barley to equal gain of treatment 1	Maintenance
III	Basal, 1/2 X $W_{kg}^{0.75}$ plus barley to produce 1/2 the gain of treatment 4	Intermediate gain
IV	Basal, 1/2 X $W_{kg}^{0.75}$ plus barley b/	Large gain

a/ X equals the value taken times $W_{kg}^{0.75}$ to determine feed requirements for maintenance.

b/ The steers received as much barley with the basal ration as they could consume in 2 hours, 3 times per day.

to a treatment (table 1); each treatment was replicated. The treatments were then randomly assigned to one of eight lots in a southern exposure, open-fronted shed. The outside one-half of the lots were a gravel base with the remaining one-half being concrete, allowing 11.15 square meters per steer. One group of four steers was slaughtered at the initiation of the trial to determine initial body composition. Prior to slaughter of the initial body composition group, all animals were fed a common ration was 28 days. This ration consisted of 0.40 kg supplement, 1.33 kg barley and 4.64 kg grass hay per head per day. The empty body weight

of the group slaughtered at the beginning of the trial was determined by the technique outlined by Lofgreen (1964). Following an overnight shrink (14 hours) without feed or water, the group of four was slaughtered and the remainder of steers placed on their respective rations on December 18, 1969.

The feed allowance for the lots being fed for maintenance (Treatments I and II) was estimated from the equation of Lofgreen et al. (1968) using estimated NE values for the feeds. The steers were weighed every two weeks and adjustments made in feed intake to obtain the desired gain. The basal ration consisted of 80% grass hay and 20% soybean oil meal (48% C.P.). The Unitan barley had a test weight of approximately .605 kg per liter and 10.97% crude protein.

The steers fed to make a predicted large gain (Treatment IV) received as much barley with the basal ration as they could consume in two hours, three times per day. The remainder of the steers were fed twice daily. The steers in the intermediate gain group (Treatment III) were fed to gain approximately one-half the gain of Treatment IV. All steers were individually fed with the amount of feed each received based on metabolic body size. Minerals and vitamins were added to each ration to meet the NRC (1963) requirements. Salt was fed free choice. All steers had access to fresh, warm water. The steers were bedded with wood shavings.

At the termination of the trial, all steers were slaughtered on the same day and final empty body weights estimated (Lofgreen et al., 1962). Body composition was estimated from carcass specific gravity by use of equations formulated by Lofgreen (1964). Energy retention was calculated from the composition of the empty body weight gain by assuming the caloric value of fat to be 9,367 kcal per kg and of protein to be 5,686 kcal per kg (Lofgreen, 1964).

The quantity of feed (per unit of $W_{kg}^{0.75}$) required to maintain the animal in energy equilibrium has a NE_m equal to the heat produced by that animal at zero feed intake (Lofgreen and Garrett, 1967, 1968b). The feed intake required to maintain energy equilibrium was measured from the relationship of heat produced to metabolizable energy intake. From this relationship, the NE_m value of the basal ration was determined. Once the NE_m of the basal is known, the NE_m of barley can be determined by the difference between that furnished by the basal and that furnished by barley to equal energy equilibrium.

The NE_p of the barley was determined by the "difference trial". The NE_p value of the feed was equal to the energy deposited in the body-weight gain brought about by feeding the particular feed in question at different levels of intake.

Trial II. Use Of NE_m And NE_p Values Of Feeds For Wintering Steers

Forty-four weaned steer calves were used in this trial. Twenty-eight of the calves were Herefords, twelve of which were produced at

the Red Bluff Research Ranch, Norris, Montana, and sixteen of which were produced at the U. S. Range Livestock Experiment Station, Miles City, Montana. The remaining sixteen calves were Hereford-Angus crossbreds, eight of which were produced at the Red Bluff Research Ranch, Norris, Montana and eight of which were produced at the Montana Agricultural Experiment Station, Bozeman, Montana.

The steers were stratified by weight, source and previous treatment into four lots of eight head each and into two lots of six head each. Previous to this trial, the steers had been on a trial involving the feeding of a medicated supplement, Aureo S-700, in which half of the steers were controls. The steers received grass hay ad libitum and 1.8 kg of a barley-beet pulp mixture prior to the beginning of the trial on January 2, 1970. Individual initial weights were obtained after an overnight shrink.

The experimental area consisted of four lots outside with fenceline bunks, two of which had concrete surfaces and two of which had half concrete surface and half slotted surface with an area of 5.85 square meters per steer. The partial slotted lots were located on the southside of the feedlot. There were electically heated waterers in each pen. The two lots of six steers each were located inside the Montana State University Nutrition Center building. The pen floors are completely slotted with a fenceline type bunk and automatic waterers,

allowing 2.97 square meters per steer. The temperature was thermostatically controlled at approximately 65°F.

Wintering rations were fed for a predicted gain as had been done by Keith and Everson (1967, 1969). The rations were formulated and fed for a predicted gain of 0.68 kg per head per day according to Gill (1968). Each ration contained either 65 or 50% roughage plus concentrate as shown in table 2. The specifications of the protein supplement is shown in table 3. Each ration was fed to one lot of steers on the south side of the feeding alley, the north side of the feeding alley and inside the building. The net energy values of the feeds used were those given by Crampton and Harris (1969) and are shown in table 4. The amount of ration a lot of steers received daily was based on their average weight, NE_m and NE_p requirement and NE_m and NE_p furnished by the respective ration. The steers were individually weighed every 14 days with a 12-hour shrink at which time the rations were recalculated. The steers were fed twice daily. Minerals and vitamins were added to each ration to meet the NRC (1963) requirements. Salt was fed free-choice.

The 84-day wintering trial was terminated March 27, 1970. The final weights of the cattle were subjected to statistical analysis of variance for two roughage treatments and three environments. The daily gains were subjected to a "t" test for paired observation to compare actual gain with the expected gain.

TABLE 2. WINTERING RATION (%)

	Treatment	
	I	II
Hay	65.0	50.0
Barley	23.3	35.0
Beet pulp	4.7	7.0
Supplement (32% C.P.)	7.0	8.0

TABLE 3. COMPOSITION OF THE THIRTY-TWO PERCENT PROTEIN SUPPLEMENT. a/

Ingredients	% of ration
Cottonseed meal	65.0
Alfalfa, dehydrated	25.0
Wheat millrun	5.0
Molasses	5.0
Vitamins A & D b/	X

a/ Protein supplement is MSU Formula No. 612.
b/ Vitamin A to furnish 20,000 I. U. per pound.
Vitamin B to furnish 4,000 I. U. per pound.

TABLE 4. NET ENERGY VALUES OF THE RATIONS (AS FED) (Trial II).

	NE Values of the feed (Mcal/kg)		NE Furnished Treatment			
			I		II	
	NE_m	NE_p	NE_m	NE_p	NE_m	NE_p
Hay	1.15	.55	.75	.36	.58	.28
Barley	1.90	1.25	.44	.29	.67	.44
Beet pulp	1.87	1.23	.09	.06	.13	.09
Supplement	1.41	.79	.10	.06	.11	.06
Total (Mcal/kg of ration)			1.38	.77	1.49	.87

Trial III. Use Of NE_m And NE_p Values Of Feeds For Fattening Steers

The forty-four steers used in Trial II were used in Trial III. The same lots were used for this trial. One-half of the steers in lots 7 and 10, fed the 65% roughage wintering ration, were replaced with one-half of the steers in lots 10 and 22, fed the 50% roughage wintering ration. The same procedure was followed for lots 25 and 26. The steers were thus stratified by weight, source and previous treatments. Initial weights were obtained on April 24, 1970, after an overnight shrink, at which time the steers had been conditioned to the respective rations. All of the steers were implanted with 36 mg of Stilbestrol per head.

The procedure used in Trial II for determining the daily ration was used in Trial III. The rations were formulated and fed for a predicted gain of 1.13 kg per head per day. Each ration contained 5 or 15% roughage plus concentrate as shown in table 5. Each ration was fed to one lot of steers on the south side of the feeding alley, the north side of the feeding alley and inside the building. The net energy values of the feeds used were those given by Crampton and Harris (1969) and are shown in table 6.

The amount of ration a lot of steers received daily was based on their average weight minus a 4% pencil shrink, NE_m and NE_p requirement for 1.13 kg daily gain and the NE_m and NE_p furnished by the respective ration. The steers were individually weighed every 14 days at which

TABLE 5. FATTENING RATION (%).

	Treatment	
	I	II
Hay	15.0	5.0
Barley	66.7	75.0
Beet pulp	13.3	15.0
Supplement (32% C.P.)	5.0	5.0

TABLE 6. NET ENERGY VALUES OF THE RATIONS (AS FED) (Trial III).

	NE Values of the Feed (Mcal/kg)		NE Furnished Treatment			
			I		II	
	NE_m	NE_p	NE_m	NE_p	NE_m	NE_p
Hay	1.15	.55	.17	.08	.06	.03
Barley	1.90	1.25	1.27	.83	1.43	.94
Beet pulp	1.87	1.23	.25	.16	.28	.18
Supplement	1.41	.79	.07	.04	.07	.04
Total (Mcal/kg of ration)			1.76	1.11	1.84	1.19

the rations were recalculated. The steers were fed twice daily. Salt was fed free choice.

The trial was determined on July 3, 1970, when individual weights were obtained after an overnight shrink. Final weights and daily gains of the steers were subjected to the same statistical analysis as Trial II.

RESULTS AND DISCUSSION

Trial I

The initial and final weights, average daily gains and average daily feed consumption data are presented in table 7.

TABLE 7. SUMMARY OF WEIGHTS, AVERAGE DAILY GAINS AND DAILY FEED CONSUMPTION OF STEERS FED FOR THE DETERMINATION OF THE NET ENERGY VALUE OF BARLEY FOR MAINTENANCE AND PRODUCTION (Trial I--December 18, 1969 to July 9, 1970--203 days).

	Treatment			
	I	II	III	IV
	Maintenance*	Maintenance*	Intermediate gain	Large gain
No steers	8	8	8	8
Average weights, kg				
Final	254.23	247.75	314.90	416.34
Initial	211.09	213.64	214.32	216.42
Gain	43.14	34.11	100.58	199.92
Daily gain	.21	.17	.50	.98
Average daily ration, kg a/				
Soybean oil meal	.71	.39	.39	.43
Barley		1.17	2.35	4.82
Hay, grass	2.87	1.43	1.59	1.79
Total	3.58	2.95	4.33	7.04

* Predicted response.
a/ Average daily rations on "as-fed" basis.

The proximate analysis of the feed ingredients used in this trial is given in table 8.

In order to determine the NE of the basal ration and of the barley, it was necessary to know the empty body weight and body composition of the initial slaughter group as determined by the comparative

TABLE 8. PROXIMATE ANALYSIS OF FEED FED IN TRIAL I (%). a/

Feed	Moisture	Crude protein	Ether extract	Ash	Crude fiber	Phos-phorus	Calcium
Soybean oil meal	11.8	46.5	2.5	5.9	3.32	.80	.29
Barley, steam rolled	10.8	9.9	1.9	2.2	4.93	.28	.06
Hay, grass	8.1	7.6	1.8	7.5	29.30	.13	.33

a/ Analyses by Chemistry Station Analytical Laboratory, Montana State University.

TABLE 9. EMPTY BODY WEIGHTS AND BODY COMPOSITION OF THE INITIAL SLAUGHTER GROUP (Trial I).

	Calf no.				
	107	114	134	140	Average a/
Individual wts, kg					
Initial	212.28	219.54	213.64	224.98	217.61
Hot carcass	114.31	123.83	114.31	119.30	117.94
Empty body	197.55	211.35	197.55	204.79	202.81
Wt in water	7.43	9.32	7.38	6.81	7.73
Fat, %	15.98	11.95	16.16	19.32	15.85
Protein, %	19.05	19.29	19.04	18.70	18.99

a/ The average applies to the values of the animals as a group.

slaughter technique developed by Lofgreen (1964). This data is presented in table 9.

Table 10 contains the data on body composition, feed consumption and energy gains which were necessary for the determination of NE. Energy retention was measured by the comparative slaughter method (Lofgreen, 1964). When measuring the energy retention, the caloric values of fat and protein are assumed to be 9,367 kcal per kg of fat and 5,686 kcal per kg of protein (Lofgreen, 1964). The treatment averages are used instead of individual steer data to decrease the variation between individuals. It has been observed by Lofgreen (1970b) that this is a more valid method of determining NE data.

Table 11 shows the heat production of the animals fed the basal and basal plus barley rations. Heat production (H) was calculated from the data in Table 10 by deducting energy retention (P) from metabolizable energy intake with all values based on $W_{kg}^{0.75}$ and feed on a dry matter (DM) basis.

Lofgreen and Garrett (1968) have shown that the quantity of feed intake per unit of $W_{kg}^{0.75}$ required to maintain an animal in energy equilibrium will have a NE equal to the heat produced at zero feed intake. The feed intake required to maintain energy equilibrium was measured by the relationship of heat produced to metabolizable energy intake. All values for heat produced and metabolizable energy intake were based on kcal per $W_{kg}^{0.75}$ per day.

Figure 2 shows the relationship between heat production and metabolizable energy intake for the 4 feed treatments plotted on

TABLE 10. AVERAGE BODY COMPOSITION, ENERGY GAIN AND FEED CONSUMPTION BY TREATMENTS (Trial I). a/

	Treatment			
	I	II	III	IV
	Basal-maintenance	½ basal plus barley-maintenance	½ basal plus barley-intermediate gain	½ basal plus barley large gain
Initial empty body weight, kg	196.74	199.11	199.75	201.75
Initial composition				
Fat, %	15.85	15.85	15.85	15.85
Protein, %	18.99	18.99	18.99	18.99
Fat, kg	31.18	31.56	31.66	31.98
Protein, kg	37.36	37.81	37.93	38.31
Final empty body weight, kg	221.14	219.83	280.34	389.76
Final body composition				
Fat, %	13.62	13.10	16.44	21.82
Protein, %	19.15	19.20	18.88	18.29
Fat, kg	30.12	28.80	46.09	85.05
Protein, kg	42.34	42.21	52.93	71.29
Gain in fat, kg	-1.06	-2.76	14.43	53.07
Gain in protein, kg	4.98	4.40	15.00	32.98
Gain in energy (P), Mcal	18.387	-.835	220.460	684.630
Total feed consumed (F), kg b/	661.79	538.97	789.68	1281.95
Mean empty body wt (W), kg	208.94	209.47	240.05	295.76
$W^{0.75}_{kg}$	54.96	55.06	60.99	71.32
$P/W^{0.75}_{kg}$, Mcal	0.3346	-0.0152	3.6171	9.6035
$F/W^{0.75}_{kg}$, kg	12.04	9.79	12.95	17.97

a/ Average of two replicated lots of 4 head each.
b/ Feed consumed is on a dry matter (DM) basis.