MONTANA STATE UNIVERSITY

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

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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DETERMINATION OF NET ENERGY OF UNITAN
BARLEY AND PREDICTION OF GAINS OF STEERS
USING NET ENERGY VALUES

by

OLAF BENJAMIN SHERWOOD

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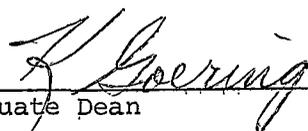
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ABSTRACT

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.

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.

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.

Gross energy (GE) of food

Digestible energy (DE) includes also:
a. energy of digestive fermentations
b. energy of gaseous products of digestion (CH_4)

Fecal energy losses from:
a. Undigested food
b. Metabolic products (mucosa, bacteria, & enzymes)

Metabolizable energy (ME)
a. energy of digestive fermentations

Urinary energy losses from:
a. residues of imperfect food-nutrient metabolism
b. endogenous catabolism

Gaseous energy losses from:
a. gaseous products of digestion (CH_4)

Lost via bowels or by belching

Net energy (NE_p & NE_m)

Production energy (NE_p)
a. stored in tissues, growth, fat, wool, etc
b. stored in products: milk, egg, fetus
c. work (expended in part as heat)

Maintenance energy (NE_m)
a. basal metabolism
b. activity at maintenance
c. sustaining body temperature

Heat increment energy from:
a. heat of nutrient metabolism
b. heat of digestive fermentations

Energy wasted as heat

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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 devel-

oped 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 $70W_{kg}^{0.75}$ 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

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

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 kilo-
calories 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 nutri-
tionists 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 require-
ment 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 dif-
ference 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 re-
quirements 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 itself 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 fermenta-
tion 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 (Treat-

ments 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 treat-

ment 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 fence-

line 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 thermos-tatically 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.

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 Intermediate gain | IV Large gain |
	Maintenance*	Maintenance*		
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
$P/W^{0.75}$, Mcal kg	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.

TABLE 11. HEAT PRODUCTION OF STEERS BY TREATMENT (Trial I).

| | Treatment | | | |
| | I | II | III | IV |
	Basal-maintenance	½ basal plus barley-maintenance	½ basal plus barley-intermediate gain	½ basal plus barley large gain
Total feed $(F/W_{kg}^{0.75})$	12.04	9.79	12.95	17.97
Metabolizable energy (ME), Mcal/kg of feed a/	1.8987	2.3307	2.4920	2.6497
$ME/W_{kg}^{0.75}$	22.8598	22.8176	32.2710	47.6160
Total energy gain, Mcal (P) $W_{kg}^{0.75}$	0.3346	-0.0152	3.6171	9.6035
Total heat production (H) $Mcal/W_{kg}^{0.75}$	22.5252	22.8328	28.6539	38.0125
Daily ME, kcal/ $W_{kg}^{0.75}$	112.6101	112.4021	158.9702	234.5617
Daily heat production $kcal/W_{kg}^{0.75}$	110.9616	112.4768	141.1522	187.2537

a/ Metabolizable energy based on values given by Crampton and Harris
    (1969) for intermountain grass hay, barley and soybean oil meal
    (solvent process) which are 1663, 3001 and 2928 kcal/kg of dry
    matter, respectively.

FIGURE 2. DETERMINATION OF FASTING HEAT PRODUCTION.

semi-logarithmic graph paper. The information used to plot the regression of heat production on metabolizable energy is shown in table 11. Heat production is plotted by its logarithmic value and extrapolated to zero feed intake for an estimate of fasting heat production. The equation describing this relationship over the range from maintenance to large gain feeding is described by the equation

$$\text{Log HP} = 1.84505 + .00184 \text{ ME}$$

where HP and ME are in kcal per $W_{kg}^{0.75}$ per day. The log of the heat produced by the fasting animal is therfore equal to $1.84505 \pm .01050$. The antilogs of these limits are .68 and 72 kcal per $W_{kg}^{0.75}$ with a mean value of 70 kcal. The average NE_m requirement of the 32 steers in Trial I can be considered to be equal to 70 kcal per $W_{kg}^{0.75}$ or .070 Mcal per $W_{kg}^{0.75}$. This is slightly lower than the value of 77 kcal per $W_{kg}^{0.75}$ reported by Lofgreen (1965). This variation could possibly be due to inadequate numbers of steers or difference in environment and feed.

If a ration is fed at a given level and the heat production determined, this quantity of heat produced may be used as one point in a regression line and the heat produced at no feed intake as the second point to establish a regression of heat production on metabolizable energy intake. From the equation describing this relationship, the metabolizable energy intake and quantity of feed consumed at energy equilibrium was determined.

Figure 3 was prepared using the heat produced and metabolizable

energy intake for the four treatments shown in table 11. Heat pro-

duced at zero feed intake was expressed by using $70W_{kg}^{0.75}$. The straight

line connecting the two points for the steers fed basal plus barley

for intermediate gain is described by the equation Log HP = 1.84510 +

.00192 ME, expressed in kcal per $W_{kg}^{0.75}$ per day. It was determined

that energy equilibrium could be maintained at a metabolizable energy

intake of 118 kcal per $W_{kg}^{0.75}$ per day. It required 0.47 kg of this

ration which is 46% basal and 54% barley, to provide 118 kcal of metab-

olizable energy.

In the same manner as that used for the basal plus barley for

intermediate gain, it was determined that at intake of 0.58, 0.48 and

0.42 kg of the basal, maintenance; basal plus barley, maintenance and

basal plus barley for large gain, respectively, metabolizable energy

intake was equal to heat production. Energy equilibrium could be

maintained at an intake of 109.6, 112.5 and 111.9 kcal of metabolizable

energy per $W_{kg}^{0.75}$ per day for basal-maintenance, basal plus barley-

maintenance and basal plus barley-large gain, respectively. The basal

alone fed for maintenance required an intake of 0.58 kg per $W_{kg}^{0.75}$ per

day to maintain energy equilibrium. The NE_m of 0.058 kg is equal to

70 kcal which is the heat production at zero feed intake. This estab-

lishes a net energy for maintenance value of 1.21 Mcal per kg of basal

FIGURE 3. RELATION OF HEAT PRODUCTION TO METABOLIZABLE ENERGY INTAKE
FOR ENERGY EQUILIBRIUM.

TABLE 12. NET ENERGY FOR MAINTENANCE OF THE BASAL RATION AND BARLEY
(Trial I).

	Treatment			
	I	II	III	IV
	Basal-maintenance	Basal, 61% barley, 39% maintenance	Basal, 46% barley, 54% intermediate gain	Basal, 32% barley, 68% large gain
Daily feed consumed at energy equilibrium, kg/W$^{0.75}_{kg}$				
Basal	0.058	0.029	0.022	0.013
Barley	0.0	0.019	0.025	0.029
NE_m, kcal/W$^{0.75}_{kg}$				
Total	70	70	70	70
From basal	70	35	27	16
From barley	0	35	43	54
NE_m, Mcal/kg, DM				
Basal	1.21	0	0	0
Barley	0	1.84	1.72	1.86

ration. Table 12 shows the determination of NE of the four rations

considered.

The NE_m of the basal was assumed to be 1.21 Mcal/kg and the NE_m

of the barley was calculated on this basis for the three rations con-

taining barley. The three values for NE_m of barley were 1.84, 1.72

and 1.86 with a mean of 1.81 Mcal/kg. These values are lower than

those of Lofgreen (1965) and Lofgreen and Garrett (1968). The value

of 1.81 Mcal/kg on a dry matter basis was relatively close to their

values of barley on as "as-fed" basis.

The NE_p was determined by the difference trial having determined

the feed intake at energy equilibrium. This was measured by the in-

crease in feed consumption and energy retention. The NE_p of the basal

ration is shown in table 13 and that of barley in table 14.

The average NE_p of barley was 1.145 Mcal/kg which was slightly

lower than the value of 1.22 Mcal/kg obtained by Lofgreen (1965). This

could be due to differences in environment, quality of barley and in-

adequate numbers of steers used to determine the NE_p value.

TABLE 13. NET ENERGY FOR PRODUCTION OF THE BASAL RATION (Trial I).

	Basal fed	
	Equilibrium	Actual consumption
Total feed consumed $(F)/W_{kg}^{0.75}$, kg	11.77	12.04
Total energy (P) retained/$W_{kg}^{0.75}$, Mcal	0	.3346
Differences		
F, kg	0	.27
P, Mcal		.3346
NE_p of basal, DM, Mcal/kg		1.24

TABLE 14. NET ENERGY FOR PRODUCTION OF BARLEY (Trial I).

	Treatment		
	II	III	IV
	Basal, 61% barley, 39% at equilibrium	Basal, 46% barley, 54% intermediate gain	Basal, 32% barley, 68% large gain
Total feed (F) consumed, $kg/W_{kg}^{0.75}$			
Basal	5.89	5.96	5.75
Barley	3.86	6.99	12.22
Total energy gain (P) Mcal/ $W_{kg}^{0.75}$	0	3.62	9.60
Differences			
F, kg			
Basal		.07	-.14
Barley		3.13	8.30 a/
P, Mcal		3.62	9.60
P from basal, Mcal		.09	0
P from barley, Mcal		3.53	9.60
NE_p of barley, Mcal/kg, DM		1.13	1.16

a/ Adjusted consumption due to a negative value for basal.

Trial II

The initial and final weights, average gain, average daily gain, average daily feed consumption, feed conversion and feed cost data for the steers during the wintering trial are presented in table 15.

Analysis of variance of total gains of steers fed 65 or 50% roughage indicated no significant difference, (P>0.05) due to treatment or environment. The average daily gains of steers fed the 65% roughage ration in lots 7, 10 and 25 were 0.76, 0.70 and 0.80 kg per day respectively. The average daily gains of steers fed the 50% roughage ration in lots 10, 22 and 26 were 0.64, 0.64 and 0.72 kg per day respectively. There was no significant difference (P>0.05) among the average daily gains.

Because the steers within each lot were group fed, a statistical analysis of feed per unit of gain could not be conducted. However, as shown in table 15, the steers fed inside on slotted floors (lots 25 and 26) had an average feed conversion of 8.67 which was slightly lower than the average of 9.61 for the steers in the lots outside. Of the steers outside, those on the south side of the feedlot (lots 7 and 10) were more efficient than those steers on the north side of the feedlot (lots 19 and 22). Except for the steers in lot 25, which had a feed conversion of 8.60, steers fed the 65% roughage ration required more feed per kg gain than those steers fed the 50% roughage ration. Average daily feed consumption was similar for the steers in each treatment.

TABLE 15. SUMMARY OF WEIGHTS, AVERAGE GAINS, AVERAGE DAILY GAINS, DAILY
FEED CONSUMPTION, FEED EFFICIENCY AND FEED COST OF GAIN FOR
STEERS FED FOR A PREDETERMINED GAIN (Trial II--January 2,
1970 to March 27, 1970--84 days). a/

	Treatment					
	I	II	I	II	I	II
	Lot no		Lot no		Lot no	
	7	10	19	22	25	26
	Outside on south side		Outside on north side		Inside on slotted floors	
No steers	8	8	8	8	6	6
Average weights, kg						
Initial	250.39	244.49	245.40	241.77	238.59	238.14
Final	313.89	305.27	303.91	295.75	307.54	298.92
Gain	63.50	60.78	58.51	53.98	68.95	60.78
Daily gain	.76	.72	.70	.64	.82	.72
Average daily ration, kg						
Barley	1.68	2.22	1.65	2.19	1.63	2.19
Beet pulp	.34	.45	.34	.44	.33	.44
Supplement, 32% C.P.	.49	.51	.49	.50	.49	.50
Hay, grass	4.67	3.18	4.71	3.14	4.55	3.13
Salt, plain	.03	.02	.02	.02	.05	.03
Average daily feed, kg	7.20	6.38	7.21	6.29	7.05	6.29
Feed per kg gain, kg	9.51	8.83	10.32	9.77	8.60	8.73
Feed cost per kg gain, $	.40	.39	.43	.43	.36	.39

a/ Treatment I was 65% roughage.
Treatment II was 50% roughage.

The proximate analysis of the feed ingredients used in this trial

is given in table 16.

At the conclusion of the trial, the average daily ration and

average weight of each lot of steers was used to calculate the expected

TABLE 16. PROXIMATE ANALYSIS OF FEED FED STEERS ON TRIAL II (%). a/

Feed	Moisture	Crude protein	Ether extract	Ash	Crude fiber	Phos-phorus	Calcium
Barley, steam rolled	10.8	9.9	1.90	2.2	4.93	.28	.06
Beet pulp	6.9	9.2	.33	6.3	17.41	.08	.46
Supplement #612	8.5	31.9	1.40	7.5	18.46	.86	.63
Hay, grass	8.1	7.6	1.80	7.5	29.30	.13	.33

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

gain in relation to the actual amount of ration received as presented in table 17.

The amount of ration each lot of steers received for each 14-day period was based on the average weight of the steers at the beginning of the period. The rations were calculated at the beginning of each period to furnish feed for an expected gain of 0.68 kg per day. When the average weights of the steers and average daily rations were recalculated at the end of the 84-day wintering period, the expected gain was 0.64 kg except for lot 19 which was 0.67 kg. The differences in expected gains were assumed to be due to rounding error in determining the amount of feed to be fed each day. Also the same amount of feed was fed each day for 14 days to each lot of steers instead of increasing the feed as

TABLE 17. SUMMARY OF AVERAGE WEIGHTS, NE_m REQUIREMENTS, NE_p REQUIREMENTS, FEED REQUIRED FOR NE_m AND NE_p, EXPECTED GAIN AND ACTUAL GAIN (Trial II). a/

	Treatment					
	I	I	I	II	II	II
	Lot no		Lot no		Lot no	
	7	19	25	10	22	26
No steers	8	8	6	8	8	6
Average weight, kg	282.14	274.88	273.07	274.88	268.98	268.53
Average daily feed, kg b/	7.18	7.19	7.00	6.36	6.26	6.26
NE_m requirement						
Mcal/day	5.35	5.25	5.22	5.25	5.17	5.16
Feed/day, kg	3.92	3.84	3.82	3.56	3.50	3.49
Available for production						
Feed/day, kg	3.26	3.35	3.18	2.80	2.76	2.77
Mcal/day	2.51	2.58	2.45	2.47	2.44	2.44
Expected gain, kg	.64	.67	.64	.64	.64	.64
Actual gain, kg	.76	.70	.82	.72	.64	.72
Ration of actual to expected gain	1.19	1.04	1.28	1.13	1.00	1.13

a/ Treatment I was 65% roughage.
    Treatment II was 50% roughage.
b/ Salt is excluded.

the weight of the steers increased. This would tend to decrease the amount of feed each lot of steers should have received.

The expected gain per day, actual gain per day and ratio of actual to expected gain per day in kg for the steers in lots 7, 10 and 25 in Treatment I (65% roughage) was 0.64, 0.76, 1.19; 0.67, 1.70, 1.04; and

0.64, 0.82, 1.28 respectively. For the steers in lots 10, 22 and 25

in Treatment II (50% roughage), it was 0.64, 0.72, 1.13; 0.64, 0.64,

1.00 and 0.64, 0.72, 1.13 respectively. In Treatment I the steers in

lot 25 had a ratio of actual to expected gain of 1.28 which was the

highest. The steers in lot 22, Treatment II, had the lowest ratio

of 1.00. Lot 19 had a higher expected gain due to an error in feed

calculations.

The mean difference between actual and expected average daily gain

for the steers in Trial II was 0.0817 kg. A statistical analysis

using the "t" test for paired observations indicated a significant dif-

ference (P<0.025) between the actual and expected gain for the 6 lots

of steers during the wintering period. There were no significant dif-

ferences observed when each treatment was analyzed.

Trial III

The initial and final weights, average gain, average daily gain,

average daily feed consumption, feed conversion and feed cost data for

the steers during the fattening trial are presented in table 18.

Analysis of variance of total gains of steers fed 15 or 5% roughage

indicated no significant difference (P>0.05) due to treatment or envi-

ronment. The average daily gains of steers fed the 15% roughage ration

in lots 7, 22 and 25 were 1.18, 117 and 1.39 kg per day respectively.

The steers fed the 5% roughage ration in lots 10, 19 and 26 gained 1.26,

TABLE 18. SUMMARY OF WEIGHTS, AVERAGE GAINS, AVERAGE DAILY GAINS,
          DAILY FEED CONTUMPTION, FEED EFFICIENCY AND FEED COST OF GAIN
          FOR STEERS FED FOR A PREDETERMINED GAIN (Trial III--April 24,
          1970 to July 3, 1970--70 days). a/

	Treatment					
	I	II	II	I	I	II
	Lot no		Lot no		Lot no	
	7	10	19	22	25	26
	Outside on south side		Outside on north side		Inside on slotted floors	
No steers	8	8	8	8	6	6
Average weights, kg						
Initial	341.11	348.36	336.12	331.13	348.36	349.27
Final	424.12	436.36	425.48	412.78	445.44	439.54
Gain	83.01	88.00	89.36	81.65	97.07	90.27
Daily gain	1.18	1.26	1.27	1.17	1.39	1.29
Average daily ration, kg						
Barley	5.78	6.33	6.17	5.67	5.99	6.42
Beet pulp	1.14	1.27	1.24	1.13	1.17	1.28
Supplement, 32% C.P.	.44	.42	.42	.43	.45	.43
Hay, grass	1.32	.42	.46	1.30	1.35	.43
Salt, plain	.04	.04	.04	.04	.05	.04
Average daily feed, kg	8.72	8.48	8.33	8.57	9.01	8.60
Feed per kg gain, kg	7.33	6.72	6.57	7.36	6.50	6.66
Feed cost per kg gain, $	.36	.34	.34	.37	.32	.35

a/ Treatment I was 15% roughage.
    Treatment II was 5% roughage.

1.27 and 1.29 kg per day respectively. There was no significant dif-

ference (P>0.05) between the average daily gains.

Because the steers within each lot were group-fed, a statistical

analysis of feed per unit of gain was not possible. As shown in table

18, the steers in lot 25 that received 15% roughage ration were the
most efficient with a feed conversion of 6.50. The steers without
shelter that received the 5% roughage ration (Treatment II) were slightly
more efficient than the steers that received the 15% roughage ration
(Treatment I). Average daily feed consumption was similar for the
steers in each treatment.

A proximate chemical analysis of the feed ingredients used in the
trial was the same as those used in Trial II.

At the conclusion of the trial, the average daily ration and aver-
age weight of each lot of steers were used to calculate the expected
gain in relation to the actual amount of ration received as presented
in table 19.

The amount of ration each lot of steers received for each 14-day
period was based on the average weight of the steers at the beginning
of the period. At the beginning of each 14-day period, the rations
for each lot of steers were calculated to furnish feed for an expected
gain of 1.13 kg per day. When the average weights and rations for the
steers were recalculated for expected gain at the end of the 70-day
fattening period, the expected gain ranged from 1.03 to 1.10 kg. The
differences in gain were assumed to be due to rounding error in deter-
mining the amount of feed to be fed each day. The average weight of
each lot of steers at the beginning of each 14-day period was shrunk
4% for the calculation of the daily feed required. Also the same amount

TABLE 19. SUMMARY OF AVERAGE WEIGHTS, NE$_m$ REQUIREMENTS, NE$_p$ REQUIRE-MENTS, FEED REQUIRED FOR NE$_m$ AND NE$_p$, EXPECTED GAIN AND ACTUAL GAIN (Trial III). a/

	Treatment					
	I	I	I	II	II	II
	Lot no		Lot no		Lot no	
	7	22	25	10	19	26
No steers	8	8	6	8	8	6
Average weight, kg	283.38	371.95	396.90	392.36	380.57	394.18
Average daily feed, kg b/	8.68	8.53	8.96	8.44	8.28	8.56
NE$_m$ requirement						
Mcal/day	6.72	6.59	6.92	6.86	6.70	6.88
Feed/day, kg	3.86	3.78	3.97	3.75	3.71	3.76
Available for production						
Feed/day, kg	4.82	4.75	4.99	4.69	4.57	4.80
Mcal/day	5.42	5.34	5.60	5.58	5.35	5.72
Expected gain	1.06	1.10	1.05	1.05	1.03	1.08
Actual gain	1.18	1.17	1.39	1.26	1.27	1.29
Ratio of actual to expected gain	1.11	1.06	1.32	1.20	1.23	1.19

a/ Treatment I was 15% roughage.
   Treatment II was 5% roughage.
b/ Salt is excluded.

of feed was fed each day for 14 days instead of increasing as the weight of the steers increased. These factors would tend to decrease the amount of feed each lot of steers received.

The expected gain per day, actual gain per day and ratio of actual to expected gain per day in kg for the steers in lots 7, 22 and 25 in

Treatment I (15% roughage) was 1.06, 1.18, 1.11; 1.10, 1.17, 1.06; and 1.05, 1.39, 1.32 respectively. For the steers in lots 10, 19 and 26 in Treatment II (5% roughage) it was 1.05, 1.26, 1.20; 1.03, 1.27, 1.23; and 1.08, 1.29, 1.19 respectively. The steers in lot 25 receiving a 15% roughage ration had the highest ratio of actual to expected gain.

The mean difference between actual and expected daily gain for the six lots of steers in Trial III was .1983 kg with the actual gain being greater than expected. A statistical analysis using the "t" test for paired observation indicated a highly significant difference (P<0.01) between the actual and expected gain for the six lots of steers in Trial III. The mean difference between actual and expected daily gain for the steers in Treatment II was .2200 kg 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 daily gain for lots 10, 19 and 26 in Treatment II. In Treatment I, the differences were nonsignificant (P>0.05). In Treatment I the differences in actual and expected gains were quite varied where as in Treatment II the differences were relatively uniform.

SUMMARY

The net energy system of evaluating feeds was studied to determine the net energy value of barley and the adaptability of established net energy values for wintering and fattening cattle. The Unitan barley had a test weight of approximately .605 kg per liter and tested 9.9% crude protein by proximate analysis.

In Trial I, 36 steer calves were used to determine the net energy value of Unitan barley for maintenance and production. Replicate lots of 4 head each were used in each treatment. The treatments used were as follows: lots 37 and 38, basal ration for maintenance; lots 36 and 39, basal plus barley for maintenance; lots 32 and 35, basal plus barley for intermediate gain and lots 33 and 34, basal plus barley for large gain.

Four of the 36 steers were slaughtered at the beginning of the trial to establish initial body composition of the steers on the trial. The remaining 32 steers were slaughtered at the conclusion of the trial to determine energy retention using the comparative slaughter technique.

The heat produced at zero feed intake was equal to the net energy requirement of the animal at energy equilibrium. The heat production at zero feed intake was measured by the regression analysis of heat production per $W_{kg}^{0.75}$ per day on metabolizable energy intake per $W_{kg}^{0.75}$ per day. In Trial I, heat production for maintenance was found to equal

70 kcal per $W_{kg}^{0.75}$ per day. This value of $70W_{kg}^{0.75}$ was less than the value of $77 W_{kg}^{0.75}$ reported by Lofgreen (1965).

By use of a regression of heat production on metabolizable energy intake, it was found that the NE_m value of barley was 1.81 Mcal per kg of dry matter.

The NE_p of barley was determined by the difference trial. The average NE_p of barley was 1.145 Mcal per kg of dry matter. This value was lower than the value of 1.22 Mcal per kg determined by Lofgreen (1965).

The lower values obtained may have been due to differences in environment, variety of barley and differences in numbers of steers used to determine the net energy values.

Trial II utilized 44 steer calves for a wintering period of 84 days. Four lots of 8 steers were fed outdoors in the feedlot and two lots of 6 steers were fed inside a building on completely slotted floors. The rations fed were either 65 or 50% roughage plus concentrate. Three of the lots of cattle received the 65% roughage ration and three lots received the 50% roughage ration.

Analysis of variance indicated no significant difference for total gains or average daily gains due to treatment or environment.

At the beginning of each 14-day feeding period, the rations each lot of steers received was calculated to furnish feed for an expected gain of 0.68 kg per day. The rations were based on established net

energy values for the feeds and requirements of the steers; however, these calculations did not provide for increased feed increments during the period as the weight of the steers increased. When the rations were recalculated at the end of the trial, the expected gain was changed to 0.64 kg per day except for lot 19 which changed to 0.67 due to an error in feeding. Actual gains ranged from 0.64 to 0.82 kg per day.

All lots gained more than expected with a mean difference between actual and expected of 0.08 kg. The "t" test for paired observations indicated a significant difference (P<0.025) between the actual and expected gain during the wintering period. Results of this trial indicates that actual gains were approximately 8 percent more than expected.

The steers used in Trial II were used in Trial III for a fattening period of 70 days. The same lots were used, only the steers were re-lotted so that equal numbers of steers from the previous treatments were in each lot. All steers were implanted with 36 mg Stilbestrol at the beginning of the fattening trial.

The rations fed were either a 15 or 5% roughage ration plus concentrate with 3 lots receiving each ration.

Analysis of variance of total gains and average daily gains indicated no significant difference due to environment or treatment.

The rations were calculated for a 1.13 kg gain per day. The expected gain when the average ration was recalculated did not equal 1.13

kg, but ranged from 1.03 to 1.10 kg. The actual gains ranged from 1.17
to 1.39 kg per day.

The mean difference between actual and expected daily gain was
0.198 kg 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 of the 6 lots of steers.

The results of this trial indicate that actual gains were approx-
imately 18 percent greater than the expected gains for fattening
cattle.

From the evaluations of the net energy system, it appears to be
one which can be used to more precisely predict weight gains than other
methods. Because of the limited information available and the results
of these trials, more research in this area should be encouraged.

APPENDIX

APPENDIX TABLE 20.   PROXIMATE ANALYSIS OF FEED FED STEERS ON TRIAL I,
II AND III (%). a/

Feed	Moisture	Crude Protein	Ether Extract	Ash	Crude Fiber	Phos- phorus	Calcium
Barley, steam rolled	10.8	9.9	1.90	2.2	4.93	.28	.06
Beet pulp	6.9	9.2	.33	6.3	17.41	.08	.46
Soybean oil meal	11.8	46.5	2.50	5.9	3.32	.80	.29
Supplement #612	8.5	31.9	1.40	7.5	18.46	.86	.63
Hay, grass	8.1	7.6	1.80	7.5	29.30	.13	.33

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

APPENDIX TABLE 21. EMPTY BODY WEIGHTS AND BODY COMPOSITION OF THE
INITIAL SLAUGHTER GROUP (Trial I).

	Calf no.				Average a/
	107	114	134	140	
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.

APPENDIX TABLE 22. INDIVIDUAL AGE, INITIAL AND FINAL WEIGHTS, WEIGHT
GAIN, AVERAGE GAIN AND AVERAGE TOTAL FEED/DAY OF
STEERS FED FOR THE DETERMINATION OF THE NET
ENERGY VALUE OF BARLEY (Trial I).

Lot no	Treat-ment	Calf no	Age in days	Initial wt kg	Final wt kg	Gain, total kg	Avg daily gain kg	Avg total feed/day a/ kg
37	I	101	466	204.57	244.94	40.37	.20	3.51
		104	463	226.34	274.42	48.08	.24	3.76
		106	465	205.48	246.75	41.27	.20	3.48
		139	465	207.74	254.92	47.18	.23	3.56
38	I	109	475	207.74	251.29	43.55	.21	3.49
		131	466	212.73	258.09	45.36	.22	3.56
		133	470	221.81	255.82	34.01	.17	3.68
		137	448	202.30	246.75	44.45	.22	3.48
36	II	119	463	209.10	234.96	25.86	.13	2.84
		123	466	195.50	231.78	36.28	.18	2.76
		126	464	217.27	251.74	34.47	.17	2.95
		128	453	234.96	281.23	46.27	.23	3.22
39	II	102	467	205.02	241.76	36.74	.18	2.88
		108	460	232.69	265.80	33.11	.16	3.12
		111	472	212.73	247.66	34.93	.17	2.95
		120	469	201.85	224.07	22.22	.11	2.78
32	III	112	464	190.96	296.65	105.69	.52	4.01
		113	446	222.71	331.12	108.41	.53	4.45
		122	447	226.79	332.93	106.14	.52	4.50
		135	464	212.73	325.68	112.95	.56	4.38
35	III	103	481	212.28	297.55	85.27	.42	4.19
		116	460	245.85	358.79	112.94	.56	4.79
		136	462	205.93	294.83	88.90	.44	4.18
		138	465	197.31	281.68	84.37	.42	4.02
33	IV	115	449	231.33	430.46	119.13	.98	7.03
		117	463	207.74	405.96	198.22	.98	7.05
		125	442	211.83	425.92	214.09	1.05	7.23
		129	451	219.08	449.51	230.43	1.14	7.57

APPENDIX TABLE 22 (continued)

Lot no	Treat- ment	Calf no	Age in days	Initial wt	Final wt	Gain, total	Ave daily gain	Ave total feed/day a/
34	IV	105	470	220.90	413.22	192.32	.95	6.85
		118	462	209.56	381.92	172.36	.85	6.32
		127	477	234.96	441.34	206.38	1.02	7.54
		130	471	195.95	382.38	186.43	.92	6.60

a/ As fed.

APPENDIX TABLE 23. INDIVIDUAL INITIAL EMPTY BODY WEIGHT, WARM CARCASS WEIGHT, CARCASS WEIGHT IN WATER, FINAL EMPTY BODY WEIGHT, AVERAGE EMPTY BODY WEIGHT AND AVERAGE EMPTY BODY WEIGHT $^{0.75}$ (Trial I).

Calf no	Initial empty body wt kg	Warm carcass wt kg	Wt in water kg	Final empty body wt kg	Avg empty body wt kg	Avg empty body wt $^{0.75}$ kg
101	190.66	127.91	7.78	217.27	203.97	53.97
104	210.95	148.78	10.82	247.53	229.24	58.91
106	191.51	129.73	9.06	219.91	205.71	54.32
139	193.61	128.37	9.85	217.94	205.77	54.33
109	193.61	122.47	9.95	209.38	201.50	53.48
131	198.26	130.63	9.30	221.21	209.74	55.11
133	206.73	134.72	9.08	227.14	216.93	56.53
137	188.54	122.02	8.32	208.73	198.63	52.91
119	194.88	127.01	9.39	215.97	205.42	54.26
123	182.21	117.48	8.84	202.15	192.18	51.62
126	202.50	123.83	8.68	211.35	206.92	54.56
128	218.98	143.33	10.75	239.63	229.30	58.93
102	191.08	130.63	9.47	221.21	206.14	54.40
108	216.87	140.16	10.66	235.03	225.95	58.28
111	198.26	136.98	9.13	230.42	214.34	56.02
120	188.12	117.93	8.10	202.80	195.46	52.27
112	177.97	150.60	9.78	250.17	214.07	55.97
113	207.57	184.16	10.44	298.83	253.20	63.47
122	211.37	181.44	12.71	294.89	253.13	63.46
135	198.26	175.99	11.59	286.99	242.62	61.48
103	197.84	162.39	11.17	267.27	232.55	59.55
116	229.13	198.22	11.67	319.22	274.17	67.38
136	191.93	165.56	10.26	271.86	231.90	59.42
138	183.89	152.86	10.20	253.45	218.67	56.86
115	215.60	261.72	14.48	411.29	313.44	74.49
117	193.61	237.68	12.79	376.44	285.02	69.37
125	197.43	254.01	13.47	400.11	298.77	71.86
129	204.18	267.62	15.01	419.85	312.01	74.24
105	205.88	245.39	12.59	387.62	296.75	71.50
118	195.31	224.98	10.20	358.02	276.66	67.84
127	218.98	258.09	11.60	406.03	312.50	74.33
130	182.63	225.43	11.66	358.67	270.65	66.73

APPENDIX TABLE 24.   INDIVIDUAL MEASUREMENTS OF CARCASS AND EMPTY BODY
SPECIFIC GRAVITY, PERCENT BODY WATER, FAT AND
PROTEIN OF TRIAL I STEERS.

Calf no	Carcass specific gravity	Empty body specific gravity	Body water %	Fat %	Protein %
101	1.06	1.06	58.86	17.70	18.85
104	1.08	1.07	63.20	12.91	19.21
106	1.08	1.07	62.15	14.04	19.16
139	1.08	1.08	64.66	11.39	19.26
109	1.09	1.08	66.31	9.72	19.28
131	1.08	1.07	62.64	13.51	19.19
133	1.07	1.07	61.26	15.01	19.09
137	1.07	1.07	61.55	14.69	19.12
119	1.08	1.07	63.64	12.45	19.23
123	1.08	1.08	64.12	11.95	19.25
126	1.08	1.07	62.24	13.94	19.16
128	1.08	1.07	64.03	12.04	19.25
102	1.08	1.07	63.12	13.00	19.21
108	1.08	1.07	64.41	11.64	19.26
111	1.07	1.07	60.99	15.31	19.07
120	1.07	1.07	61.73	14.49	19.13
112	1.07	1.06	60.38	16.97	18.22
113	1.06	1.05	57.35	19.47	18.65
122	1.08	1.07	62.23	13.95	19.16
135	1.07	1.06	60.70	15.63	19.05
103	1.07	1.08	61.76	14.45	19.13
116	1.06	1.06	58.15	18.53	18.76
136	1.07	1.06	59.28	17.22	18.90
138	1.07	1.07	61.01	15.27	19.07
115	1.06	1.05	56.86	20.06	18.57
117	1.06	1.05	56.31	20.73	18.47
125	1.06	1.05	56.02	21.08	18.43
129	1.06	1.05	57.13	19.73	18.61
105	1.05	1.05	55.39	21.85	18.30
118	1.05	1.04	53.22	24.62	17.83
127	1.05	1.04	53.07	24.80	17.79
130	1.05	1.05	55.54	21.66	18.33

APPENDIX TABLE 25.   INDIVIDUAL METABOLIZABLE ENERGY INTAKE, ENERGY
                     RETAINED AND HEAT PRODUCED BY TRIAL I STEERS.

Calf no	Metabolizable energy intake kcal/day	Energy retained kcal/day	Heat produced kcal/day
101	6105.90	513.30	5592.60
104	6488.39	142.00	6346.39
106	6043.36	185.20	5858.16
139	6189.05	-124.70	6313.75
109	6059.99	-375.90	6435.89
131	6201.70	63.10	6138.60
133	6380.65	175.60	6205.05
137	6043.36	151.20	5892.16
119	5979.49	-57.90	6037.39
123	5805.58	-97.20	5902.78
126	6207.25	-64.70	6271.95
128	6765.47	-142.70	6908.17
102	6084.69	103.30	5981.39
108	6608.92	-208.70	6817.62
111	6207.25	353.70	5853.55
120	5852.22	66.20	5786.02
112	9020.58	987.40	8033.18
113	10001.46	1623.00	8378.46
122	10112.10	811.50	9300.60
135	9832.26	1095.90	8736.36
103	9389.72	714.90	8674.82
116	10769.02	1511.90	9257.12
136	9419.00	1175.20	8243.80
138	9020.58	817.20	8203.38
115	16676.63	3223.20	13453.43
117	16805.01	3102.50	13702.51
125	17271.06	3462.60	13808.46
129	18079.49	3432.00	14647.49
105	16290.86	3294.80	12996.06
118	14932.12	3387.40	11544.72
127	18002.84	3904.30	14098.54
130	15773.51	3119.90	12653.61

APPENDIX TABLE 26.   NET ENERGY VALUES OF THE RATIONS IN TRIAL II.

	NE values of the feeds (Mcal/lb)		NE furnished treatment			
			I		II	
	NE_m	NE_p	NE_m	NE_p	NE_m	NE_p
Hay	.52	.25	.34	.16	.26	.13
Barley	.85	.57	.20	.13	.30	.20
Beet pulp	.85	.56	.04	.03	.06	.04
Supplement	.64	.36	.04	.03	.05	.03
Total (Mcal/lb of ration)			.62	.35	.67	.40

APPENDIX TABLE 27. INDIVIDUAL INITIAL AND FINAL WEIGHTS, WEIGHT GAIN
AND AVERAGE DAILY GAIN (TRIAL II).

| Lot no | Treatment | Ear tag no | Wintering Trial (84 days) January 2, 1970 to March 27, 1970 | | | |
			Initial wt	Final wt	Gain, total	Avg daily gain
			lb	lb	lb	lb
7	I	147	511	665	154	1.83
		73	526	651	125	1.49
		74	468	617	149	1.77
		91	613	761	148	1.76
		97	624	743	119	1.42
		146	507	657	150	1.79
		99	560	693	133	1.58
		957	603	747	144	1.71
10	II	68	541	685	144	1.71
		76	495	663	168	2.00
		79	473	611	138	1.64
		144	533	649	116	1.38
		142	511	641	130	1.55
		100	583	711	128	1.52
		69	558	676	118	1.40
		917	617	746	129	1.54
19	I	78	527	669	142	1.69
		77	476	588	112	1.33
		66	539	681	142	1.69
		143	562	707	145	1.73
		70	525	631	106	1.26
		93	533	653	120	1.43
		72	587	699	112	1.33
		914	579	736	157	1.87
22	II	145	560	679	119	1.42
		64	501	698	197	2.35
		75	475	610	135	1.61
		90	484	560	76	.90
		71	537	656	119	1.42
		98	529	620	91	1.08
		92	580	681	101	1.20
		947	594	709	115	1.37

APPENDIX TABLE 27 (continued)

Lot no	Treatment	Ear tag no	Wintering Trial (84 days) January 2, 1970 to March 27, 1970			
			Initial wt	Final wt	Gain, total	Avg daily gain
			lb	lb	lb	lb
25	I	80	501	645	144	1.71
		65	490	637	147	1.75
		148	602	738	136	1.62
		95	494	621	127	1.51
		930	559	736	177	2.11
		962	509	688	179	2.13
26	II	81	533	670	137	1.63
		94	526	684	158	1.88
		149	468	550	82	.98
		96	520	649	129	1.54
		963	548	671	123	1.46
		955	557	729	172	2.05

APPENDIX TABLE 28. SUMMARY OF WEIGHTS, AVERAGE GAINS, AVERAGE DAILY GAINS, AVERAGE FEED CONSUMPTION, FEED EFFICIENCY AND FEED COST OF GAIN FOR STEERS FED FOR A PRE-DETERMINED GAIN (Trial II--January 2, 1970 to March 27, 1970--84 days). a/

	Treatment					
	I	II	I	II	I	II
	Lot no		Lot no		Lot no	
	7	10	19	22	25	26
	Outside on south side		Outside on north side		Inside on slotted floors	
No steers	8	8	8	8	6	6
Average weights, lb						
Initial	552	539	541	533	526	525
Final	692	673	670	652	678	659
Gain	140	134	129	119	152	134
Daily gain	1.67	1.59	1.54	1.42	1.81	1.59
Average daily ration, lb						
Barley	3.70	4.89	3.64	4.82	3.59	4.83
Beet pulp	.75	.99	.74	.97	.73	.97
Supplement, 32% C.P.	1.08	1.12	1.09	1.11	1.08	1.10
Hay, grass	10.29	7.02	10.37	6.91	10.03	6.90
Salt, plain	.06	.05	.06	.06	.10	.07
Average daily feed, lb	15.88	14.07	15.90	13.87	15.53	13.87
Feed per cwt gain, lb	951.35	883.15	1031.58	976.78	860.06	872.77
Feed cost per cwt gain, $	17.95	17.84	19.46	19.74	16.26	17.52

a/ Treatment I was 65% roughage.
   Treatment II was 50% roughage.

APPENDIX TABLE 29. SUMMARY OF AVERAGE WEIGHTS, NE_m REQUIREMENTS, NE_p REQUIREMENTS, FEED REQUIRED FOR NE_m AND NE_p, EXPECTED GAIN AND ACTUAL GAIN (Trial II). a/

	Treatment					
	I	I	I	II	II	II
	Lot no		Lot no		Lot no	
	7	19	25	10	22	26
No steers	8	8	6	8	8	6
Average weight, lb	622	606	602	606	593	592
Average daily feed, lb b/	15.82	15.84	15.43	14.02	13.81	13.80
NE_m requirement						
Mcal/day	5.35	5.25	5.22	5.25	5.17	5.16
Feed/day, lb	8.63	8.47	8.42	7.84	7.72	7.70
Available for production						
Feed/day, lb	7.19	7.37	7.01	6.18	6.09	6.10
Mcal/day	2.51	2.58	2.45	2.47	2.44	2.44
Expected gain, lb	1.41	1.47	1.41	1.41	1.41	1.41
Actual gain, lb	1.67	1.54	1.81	1.59	1.42	1.59

a/ Treatment I was 65% roughage.
    Treatment II was 50% roughage.
b/ Salt is excluded.

APPENDIX TABLE 30. "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL II, TREATMENT I.

Lot	Actual gain	Expected gain	Difference
7	1.67	1.41	.26
19	1.54	1.47	.07
25	1.81	1.41	.40
ΣX	5.02	4.29	.73
$\overline{X}$	1.67	1.43	

$\overline{d}$ = .2325

$s^2_{\overline{d}}$ = .0092

$s_{\overline{d}}$ = .0960

t = 2.53 NS

APPENDIX TABLE 31. "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL II, TREATMENT II.

Lot	Actual gain	Expected gain	Difference
10	1.59	1.41	.18
22	1.42	1.41	.01
26	1.59	1.41	.18
ΣX	4.60	4.23	.37
$\overline{X}$	1.53	1.41	

$\overline{d}$ = .0649

$s^2_{\overline{d}}$ = .0032

$s_{\overline{d}}$ = .0562

t = 2.19 NS

APPENDIX TABLE 32.   "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL II, TREATMENTS I
AND II.

Lot	Actual gain	Expected gain	Difference
7	1.67	1.41	.26
19	1.54	1.47	.07
25	1.81	1.41	.40
10	1.59	1.41	.18
22	1.42	1.41	.01
26	1.59	1.41	.18
ΣX	9.62	8.52	
X	1.60	1.42	

$\bar{d} = .1833$

$s^2_{\bar{d}} = .0032$

$S_{\bar{d}} = .0565$

$t = 3.244*$

* Significant at the 2.5% level.

APPENDIX TABLE 33.   ANALYSIS OF VARIANCE OF TOTAL GAINS OF THE STEERS
IN TRIAL II.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F value
Treatments	1	203.195	203.195	2.5067 NS
Environments	2	351.243	175.622	2.1666 NS
Treatments X environments	2	35.9588	17.9794	NS
Error	38	3080.2876	81.0602	
Total	43	3670.6844		

APPENDIX TABLE 34. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS OF THE
STEERS IN TRIAL II.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F value
Treatments	1	.02853	.02853	2.47 NS
Environments	2	.04964	.02482	2.15 NS
Treatments X environments	2	.00499	.00249	.21 NS
Error	38	.43946	.01156	
Total	43	.52263		

APPENDIX TABLE 35. NET ENERGY VALUES OF THE RATIONS IN TRIAL III.

| | NE values of the feeds (Mcal/lb) | | NE furnished treatment | | | |
| | | | I | | II | |
	NE_m	NE_p	NE_m	NE_p	NE_m	NE_p
Hay	.52	.25	.08	.04	.03	.01
Barley	.85	.57	.57	.38	.64	.43
Beet pulp	.85	.56	.11	.07	.13	.08
Supplement	.64	.36	.03	.02	.03	.02
Total (Mcal/lb of ration)			.79	.51	.83	.54

APPENDIX TABLE 36.   INDIVIDUAL, INITIAL AND FINAL WEIGHTS, WEIGHT GAIN
AND AVERAGE DAILY GAIN (TRIAL III).

| Lot no | Treatment | Ear tag no | Fattening Trial (70 days) April 24, 1970 to July 3, 1970 | | | |
			Initial wt	Final wt	Gain, total	Avg daily gain
			lb	lb	lb	lb
7	I	70	703	839	136	1.94
		73	733	916	183	2.61
		66	766	957	191	2.73
		99	734	907	173	2.47
		143	781	969	188	2.69
		146	732	908	176	2.51
		147	733	927	194	2.77
		914	831	1058	227	3.24
10	II	64	784	1002	218	3.11
		68	786	991	205	2.93
		69	761	944	183	2.61
		71	743	906	163	2.33
		76	766	963	197	2.81
		92	771	946	175	2.50
		144	743	938	195	2.79
		947	786	1007	221	3.16
19	II	77	637	836	199	2.84
		72	780	975	195	2.79
		74	646	863	217	3.10
		78	709	864	155	2.21
		91	817	986	169	2.41
		93	731	896	165	2.36
		97	794	1032	238	3.40
		957	821	1048	227	3.24
22	I	75	696	884	188	2.69
		79	701	903	202	2.89
		90	619	766	147	2.10
		98	676	809	133	1.90
		100	796	987	191	2.73
		142	737	925	188	2.69
		145	778	968	190	2.71
		917	838	1037	199	2.84

APPENDIX TABLE 36 (continued)

Lot no	Treatment	Ear tag no	Fattening Trial (70 days) April 24, 1970 to July 3, 1970			
			Initial wt	Final wt	Gain, total	Avg daily gain
			lb	lb	lb	lb
25	I	80	766	989	223	3.19
		94	790	1037	247	3.53
		95	722	937	215	3.07
		149	642	821	179	2.56
		930	836	1053	217	3.10
		955	854	1056	202	2.89
26	II	65	739	908	169	2.41
		81	771	963	192	2.74
		96	732	886	154	2.20
		148	816	1070	254	3.63
		962	768	995	227	3.24
		963	791	992	201	2.87

APPENDIX TABLE 37.   SUMMARY OF WEIGHTS, AVERAGE GAINS, AVERAGE DAILY
GAINS, DAILY FEED CONSUMPTION, FEED EFFICIENCY
AND FEED COST OF GAIN FOR STEERS FED FOR A PRE-
DETERMINED GAIN (Trial III--April 24, 1970 to
July 3, 1970--70 days). a/

	Treatment					
	I	II	II	I	I	II
	Lot no		Lot no		Lot no	
	7	10	19	22	25	26
	Outside on south side		Outside on north side		Inside On slotted floors	
No steers	8	8	8	8	6	6
Average weights, lb						
Initial	752	768	741	730	768	770
Final	935	962	938	910	982	969
Gain	183	194	197	180	214	199
Daily gain	2.61	2.77	2.81	2.57	3.06	2.84
Average daily ration, lb						
Barley	12.74	13.96	13.60	12.51	13.20	14.16
Beet pulp	2.52	2.80	2.73	2.49	2.59	2.83
Supplement, 32% C.P.	.97	.93	.92	.95	.99	.94
Hay, grass	2.90	.92	1.01	2.86	2.97	.95
Salt, plain	.09	.08	.09	.09	.10	.09
Average daily feed, lb	19.22	18.69	18.35	18.90	19.85	18.97
Feed per cwt gain, lb	733.06	672.29	656.62	735.88	649.58	665.87
Feed cost per cwt gain $	16.50	15.50	15.38	16.75	14.33	15.67

a/   Treatment I was 15% roughage.
     Treatment II was 5% roughage.

APPENDIX TABLE 38. SUMMARY OF AVERAGE WEIGHTS, NE_m REQUIREMENTS, NE_p REQUIREMENTS, FEED REQUIRED FOR NE_m AND NE_p, EXPECTED GAIN AND ACTUAL GAIN (Trial III). [a]

	Treatment					
	I	I	I	II	II	II
	Lot no		Lot no		Lot no	
	7	22	25	10	19	26
No steers	8	8	6	8	8	6
Average weight, lb	843	820	875	865	839	869
Average daily feed, lb [b]	19.13	18.81	19.75	18.61	18.26	18.88
NE_m requirement						
Mcal/day	6.72	6.59	6.92	6.86	6.70	6.88
Feed/day, lb	8.51	8.34	8.76	8.27	8.17	8.29
Available for production						
Feed/day, lb	10.62	10.47	10.99	10.34	10.09	10.59
Mcal/day	5.42	5.34	5.60	5.58	5.35	5.72
Expected gain, lb	2.33	2.43	2.31	2.32	2.28	2.37
Actual gain, lb	2.61	2.57	3.06	2.77	2.81	2.84

[a] Treatment I was 15% roughage.
   Treatment II was 5% roughage.
[b] Salt is excluded.

APPENDIX TABLE 39. ANALYSIS OF VARIANCE OF TOTAL GAINS OF THE STEERS IN TRIAL III.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F value
Treatments	1	26.7408	26.7408	.0264 NS
Environments	2	448.004	224.002	2.209 NS
Treatments X environments	2	263.617	131.936	1.301 NS
Error	38	3854.112	101.424	
Total	43	45924.738		

APPENDIX TABLE 40. ANALYSIS OF VARIANCE OF AVERAGE DAILY GAINS OF THE STEERS IN TRIAL III.

Source of variation	Degrees of freedom	Sums of squares	Mean square	F value
Treatments	1	.0052	.0052	.25 NS
Environments	2	.0918	.0459	2.22 NS
Treatments X environments	2	.0546	.0273	1.32 NS
Error	38	.7879	.0207	
Total	43	.9395		

APPENDIX TABLE 41. "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL III, TREATMENTS I
AND II.

Lot	Actual gain	Expected gain	Difference
7	2.61	2.33	.28
22	2.57	2.43	.14
25	3.06	2.31	.75
10	2.77	2.32	.45
10	2.81	2.28	.53
26	2.84	2.37	.47
ΣX	16.66	14.04	2.62
X̄	2.78	2.34	

$\bar{d}$ = .4366

$s^2_{\bar{d}}$ = .0074

$s_{\bar{d}}$ = .0861

t = 5.071**

** Highly significant at 1% level.

APPENDIX TABLE 42. "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL III, TREATMENT I.

Lot	Actual gain	Expected gain	Difference
7	2.61	2.33	.28
22	2.57	2.43	.14
25	3.06	2.31	.75
ΣX	8.24	7.07	1.17
$\overline{X}$	2.75	2.36	

$\overline{d}$ = .3900

$s^2_{\overline{d}}$ = .0340

$s_{\overline{d}}$ = .1844

t = 2.115 NS

APPENDIX TABLE 43. "t" TEST FOR PAIRED OBSERVATIONS OF ACTUAL AND EX-
PECTED GAINS FOR STEERS IN TRIAL III, TREATMENT II.

Lot	Actual gain	Expected gain	Difference
10	2.77	2.32	.45
10	2.81	2.28	.53
26	2.84	2.37	.47
ΣX	8.42	6.97	
X̄	2.81	2.32	

$\bar{d}$ = .4833

$s_{\bar{d}}^2$ = .0006

$s_{\bar{d}}$ = .0245

t = 19.7265**

** Highly significant at the 1% level.

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