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

A thesis submitted to the Graduate Faculty in partial fulfillment of the Requirements for the degree of MASTER OF SCIENCE in Animal Science
Montana State University

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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Signature *Olaf Benjamin Sherwood*

Date *August 5, 1970*

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OLAF BENJAMIN SHERWOOD

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Approved:

R. L. Blackwell by O. O. Thomas

Head, Major Department

O. O. Thomas

Chairman, Examining Committee

K. Goering

Graduate Dean

MONTANA STATE UNIVERSITY
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TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

LIST OF TABLES

LIST OF TABLES
(continued)

LIST OF TABLES
(continued)

Appendix

LIST OF TABLES
(continued)

LIST OF FIGURES

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)
    - Metabolizable energy (ME)
      - a. energy of digestive fermentations
      - 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
    - 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
  - Fecal energy losses from:
    - a. Undigested food
    - b. Metabolic products (mucosa, bacteria, & enzymes)

FIGURE 1. CONVENTIONAL BIOLOGICAL PARTITION OF FOOD ENERGY.

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

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

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

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

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

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

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

There are three expressions of net energy (NE) (Lofgreen and Garrett, 1967) which are commonly used and extremely important to understand when referring to a discussion of NE: (1) net energy for maintenance alone (NE_p), (2) net energy for production above maintenance (NE_m) and (3) net energy for maintenance plus production (NE_{m+p}).

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

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

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

Development of Net Energy Values

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

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

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

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

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

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

Lofgreen and Garrett (1968b) reported that in order to measure the NE_m requirement it is necessary to know the heat production of the fasting animal since this amount of net energy must be furnished to the animal to keep it in energy equilibrium. The heat production of the fasting animal has been considered to be equal to basal metabolism which is often expressed as $70W_{kg}^{0.75}$ 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

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

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

Garrett, Meyer and Lofgreen (1959) expressed maintenance requirement of sheep as $33W^{0.75}$ and cattle as $38W^{0.75}$ or a combined species requirement of $35W^{0.75}$ where the values are calculated in kilocalories per day when W is in pounds. Reasonable estimates of the requirement to maintain energy equilibrium, in terms of the different measures of food energy, can be made from the following relationships:

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

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

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

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

W is in pounds, TDN in pounds per day; and De, ME and NE are in 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 nutritionists call a "difference trial". Such a trial measures the increase in energy gained due to an increase in the amount of feed intake above maintenance. In a difference trial, the lower level of feed is fed to maintain energy equilibrium and the higher level of feed intake is free choice. Lofgreen and Garrett (1967) directly determined the NE_p