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Use of Energy Values in Ration Formulation

This NebGuide contains information on the use of high energy values in ration formulation.

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Ruminants digest feedstuffs primarily by fermentation in the rumen. This allows ruminant animals to use both roughages and grains as sources of carbohydrates for energy. Part of the carbohydrates pass through the rumen and are digested in the abomasum and small intestine. Most carbohydrates in feeds are converted to either acetic, propionic or butyric acid by rumen bacteria and protozoa. These short chain fatty acids are then absorbed through the rumen wall into the blood stream and eventually are used for energy in body tissue.

The Relationship of Rations to Digestive Disturbances

The type of short chain fatty acids produced in the rumen is a function of the type and amount of bacteria and protozoa in the rumen, which in turn is primarily determined by the types of feedstuffs fed. Some bacteria and protozoa can digest cellulose and hemicellulose but not starch. Others can digest starch but not cellulose and hemicellulose. Some can use both, but can use one better than the other. When the ration is changed from forage to grain the population shifts toward more starch digesters. Starch digesting bacteria produce more propionic acid relative to acetic acid than cellulose digesters. In addition, grain is mostly starch and is rapidly digested. Thus a switch to a high grain ration results in a

rapid production and increase in the rumen concentration of short chain fatty acids and a rapid increase in rumen acidity.

During sudden introduction of large amounts of grain in the ration, the starch digesting bacteria, *Streptococcus bovis*, rapidly increase. Eighty to 85 percent of the acid produced by this species is lactic acid. Lactic acid is normally converted to propionic acid in the rumen. Small quantities of lactic acid can be used efficiently. When too much lactic acid is produced, blood acidity increases, leading to an acute acid indigestion, posterior incoordination, dullness and sometimes death. High levels of lactic acid result in damage to the rumen wall, microbial penetration of the rumen wall and subsequent invasion of the liver, resulting in rumen wall ulcerations and liver abscesses.

When cattle are adapted to high grain rations, a new microbial balance develops in which *Streptococcus bovis* is not exceptionally high and in which other species predominate. Cellulose and hemicellulose are digested more slowly than starch and soluble carbohydrates. This results in a low total concentration of acids at any one time. Thus one can switch rather rapidly from a grain to a forage ration, but not from a forage to a grain ration. A rapid switch to a grain ration without allowing the proper microbial balance to develop can result in digestive disorders such as acidosis, bloat, founder and enterotoxemia. The same thing occurs during infrequent feeding of grains or when animals have been "off feed." They gorge themselves in a short time when fed, resulting in a rapid shift in microbial population and accumulation of acids, particularly lactic acid.

Gradually introducing grains over a period of 2 to 3 weeks or more and then feeding high levels of grain continuously will allow the proper balance of rumen microbial population to develop. Roughage may then be kept at a low level by avoiding abrupt changes in the ration and by using good feedbunk management.

Crude Fiber as a Source of Energy

The digestibility of forage is greatly affected by its crude fiber content. Crude fiber refers to the content of complex carbohydrates (cellulose, hemicellulose and lignin) which are found in cell walls. Feeds high in crude fiber are usually less digestible than those high in starches and sugars because lignin is nearly indigestible. As a plant matures lignin content increases, resulting in less digestible nutrients. As lignin increases, other nutrients become less available for digestion because lignin prevents the bacteria from reaching part of the digestible nutrients in the cell wall. Sugars and fat depress fiber digestibility, whereas protein increases fiber digestibility.

Fat As An Energy Source For Ruminants

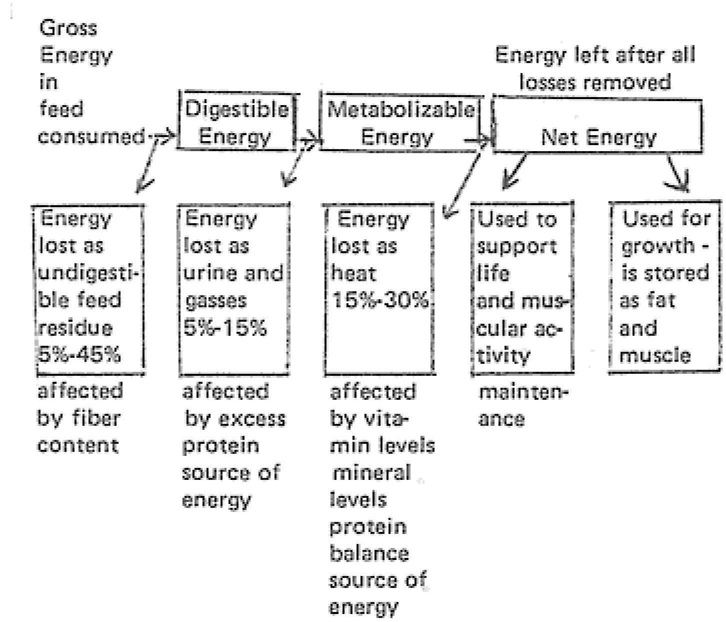
Beef cattle cannot be fed high levels of fat because they are unable to digest large quantities of fat at one time. Up to 5 to 8 percent fat can be added to beef rations, resulting in an 8 to 10 percent increase in feed efficiency because of the high energy value of fat. Levels higher than this can depress performance. The use of fat in a ration depends on the relative cost of grains and fat as energy sources. Fat has a 10 percent higher digestibility and has 2.25 times the energy value of grains per pound. Therefore, it is worth 2.5 times the cost of grain as an energy source if not fed in excess of the above limitations.

EXPRESSING ENERGY VALUES OF FEEDS

Calories are used to express the energy value of feedstuffs. One calorie is the amount of heat required to raise the temperature of 1 gram of water 1 degree centigrade. One Kcal = 1,000 calories. One Mcal or therm = 1 million calories.

The combustion of a foodstuff results in the production of heat. The heat produced is measured as calories and is called the total or gross energy content of the feed. The body obtains energy for its physiological processes by combusting glucose and fatty acids obtained from feed. The amount of energy that is stored by the animal can be determined by measuring the amount of fat and protein stored and then calculating the calories (potential heat) that the muscle and fat tissue contain. By knowing the energy content of the fat and muscle tissue deposited during growth, the net energy required to obtain a given amount of weight gain can be calculated. The energy value of a feed depends on the amount and proportions of carbohydrates, fat and protein it contains.

Through various digestive and metabolic processes, about 60 percent of the total combustible energy in grains and about 80 percent of the total combustible energy in roughages is lost in feces, urine, gasses and heat. The size of these losses and the main factors that affect them are summarized in the following graph.



The major objective of formulating rations is to put feedstuffs together in the combination that will give least-cost production. The useful energy in feeds must be known before a least-cost ration can be accurately calculated. Therefore, selecting the system that best describes the useful energy in feedstuffs and consistently relates these feed values to the requirements of growing and finishing beef cattle is economically important.

Gross Energy (GE)

GE represents the total combustible energy in a feedstuff, and is expressed as Kcal or Mcal per lb. GE is determined directly by burning a small amount of the feedstuff and measuring the heat liberated. GE does not vary greatly in feeds, except for those high in fat. For example, 1 lb of corn cobs contains about the same amount of GE as 1 lb of shelled corn. Therefore, GE does little to describe the useful energy in feeds for beef cattle.

Digestible Energy (DE)

DE is that portion of the GE in a feed that is not excreted in the feces, and is expressed as Kcal or Mcal

per lb. DE is determined by measuring the energy that is contained in the feces produced from a given amount of the feed. Then DE is calculated by subtracting the energy lost in the feces from the GE and then dividing this result by the amount of feed fed. Some energy in the feces comes from body tissues and secretions which are eliminated.

Grain processing generally increases digestibility. The major factor affecting variability in DE values of feedstuffs is fiber content. DE more accurately describes the useful energy in a feedstuff than does GE. DE does not take into account the energy lost as urine, gas or heat.

Total Digestible Nutrients (TDN)

TDN is commonly used to represent the same energy portion in a feed as DE and is expressed as a percent. TDN is the proportion of the energy sources (fiber, protein, sugars and starches and fat) in a feed that are not excreted in the feces. TDN is determined in a digestion trial similar to DE, except the feed fed and feces produced are chemically analyzed to determine their content of fiber, protein, sugars and starches, nitrogen free extract (NFE) and fat. TDN is then calculated by adding these energy sources not excreted in the feces and then dividing this result by the amount of feed fed.

TDN is used in practice as an equivalent to DE since both adjust for fiber digestibility but not for gas, urine and heat loss. The major factor affecting variation in TDN values of feeds is fiber content of the feed. TDN may be the preferred value for calculating near-maintenance wintering rations because the energy used in all metabolic processes is included. Many of these processes produce heat which is available to keep the body warm.

Metabolizable Energy (ME)

ME represents that portion of the DE that is not lost in urine and gas. The ME value of a feed is determined similar to DE with the energy lost as urine and gas being measured and deducted from the DE value. Then the energy remaining is divided by the amount of feed fed to calculate the ME value of the feed. ME more accurately describes the useful energy in a feed than does GE or DE. The major factor affecting variability in ME values of feedstuffs is also fiber content.

Net Energy (NE)

NE represents that portion of the ME that is not used in the process of digestion and metabolism. It is the amount of energy that can be used for maintenance or production. A feed has two net energy values. The net energy value for maintenance (NE_m) represents the energy in the feed that is available for supporting the animal's maintenance functions (beating of the heart and functioning of the other organs and muscular activity). The energy value of a feed for growth (NE_g) represents the energy in a feed that is available for supporting growth of body tissues and is actually deposited as protein and fat tissue gain.

The NE_m is calculated by determining the amount of the feed required to keep an animal of a given size at a constant weight. This amount of feed has an energy value equal to the animal's maintenance requirement. For example, a 600 pound steer requires 5.21 Mcal of net energy daily for maintenance. If 10 pounds of alfalfa hay were required to maintain this weight, then this hay would have a NE_m value of 5.21/10=0.52 Mcal per pound.

The NE_g value of a feed is calculated by determining the energy deposited as fat and protein in body

tissue from feed consumed above that needed for maintenance. To make this determination, representative cattle are first slaughtered to determine the energy contained in their body tissues at the start of the experiment. Then remaining cattle are slaughtered at the end of the experiment, and the Mcal gained from the feed fed is equal to the Mcal in the body tissues at the end of the trial minus that calculated to be in the body tissues at the start. For example, in the same 600 pound steers if an average of 18 pounds of alfalfa hay were consumed daily and 10 pounds were required daily for maintenance, then 8 lb per day were used for gain. If the steer gained 2.0 Mcal as body tissue per day, then the alfalfa hay has a NE_gvalue of 2/8=0.25 Mcal per pound.

All feeds have higher net energy values for maintenance than for growth. Roughages are lower in both NE_m and NE_g than concentrates for two reasons. First, because of their fiber content less of the energy is digestible and more is lost as feces. Second, during the process of transforming the energy in the feed into a form usable by the animal (fermentation in the rumen and breakdown of the fatty acids produced) a higher proportion of the ME is lost as heat from roughages than from grains. For example, corn contains 1.34 Mcal of ME per pound and has a heat loss of approximately 0.55 Mcal per pound . Prairie hay contains 0.75 Mcal of ME per pound and has a heat loss of 0.42 Mcal per pound when both the corn and prairie hay are fed in a typical growing ration, dry basis. Even though there was more total heat produced per pound of corn fed, the proportion of the ME lost as heat from the corn is 0.55 divided by 1.34 = 41 percent and the proportion of the ME lost as heat from the prairie hay is 0.42 divided by 0.75 = 56 percent. In this case there was about 1.3 Mcal of heat produced for every Mcal of net energy consumed from the prairie hay but there was only 0.7 Mcal from corn.

The proportion of the heat produced from a ration that is usable during cold weather primarily depends on the total net energy intake, wind velocity and air temperature. A higher proportion of heat production per unit of net energy intake is detrimental during hot weather. Thus, high levels of roughages are better utilized during the winter than during the summer.

Applying Energy Values in Formulating Rations

DE, TDN and ME are related, and one value is used to estimate the others, as the major factors that affect one also affects the others. One pound TDN = 2 Mcal of DE. ME is approximately equal to 82 percent of DE. Therefore, 1 pound of TDN = 2 Mcal of DE = 1.64 Mcal of ME. It is more difficult to directly relate these to NE, however, because of the extreme variation in heat loss from one feed to another. This is illustrated by the fact that 1 pound of TDN from corn contains more NE than does 1 pound of TDN from hay, primarily because TDN does not take into account the difference in heat loss per unit of TDN or ME, as previously discussed.

NE adjusts for the variation in heat loss as well as the other energy losses, making NE values more consistent from one feed to another. In addition, the net energy value can be separated in NE_m and NE_g further reducing the variation in results from one feed to another. For example, shelled corn has a NE_m value of 1.04 Mcal and a NE_g value of 0.67 Mcal per pound and fair quality alfalfa hay has a NE_m of 0.55 Mcal and a NE_g of 0.21 Mcal per pound. This alfalfa is worth 53 percent as much as the corn for maintenance, 0.55 divided by 1.04, but only 31 percent as much as the corn for growth, 0.21 divided by 0.67. Separation allows a more accurate prediction of gains from a given combination of feedstuffs. The hay should be used in the maintenance or wintering type ration and the corn in the finishing ration where both types of feeding programs are being used. Thus, the net energy system should help us to more correctly estimate the useful energy in a feedstuff than does DE, ME or TDN.

When appropriate net energy values are assigned to the feedstuffs used in the ration and the ration is

balanced for all other nutrients, gains predicted from the feed consumed will usually be within 5 to 10 percent of actual gains. Factors such as extremes in weather and cattle, variations in quality of feedstuffs, pen conditions and compensatory growth will reduce the predictability of gains. One of the greatest problems is to assign proper NE values to the feeds used. More research is needed to properly define the NE_m and NE_g values of various feeds, particularly forages, under various environmental conditions.

[1]Adapted from EC72-231, authored by Danny G. Fox, South Dakota State University.

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