NEWS TO EWES

What Is This Stuff We Call Energy?

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Introduction

All the processes that take place in the animal body, as food is ingested and metabolized, involve energy changes. The word "energy" is from the Greek word ergon meaning work. The word was introduced by Thomas Young in 1807 and he defined it as "the ability to do work". Of the many forms of energy, heat, kinetic, radiant, and chemical energy are the most important in nutrition. Heat energy will be emphasized in this article.

Heat Energy

Although all forms of energy can be converted into heat energy, the heat energy represented by the constituents of the diet and that involved in all body processes provides the most convenient basis for describing nutritional energetics. The body is not a heat engine. Life processes are not operated by temperature differences. Therefore, the heat produced in these processes is an end product, not a motive power for them. It is useful only to help keep the body warm, but its production in the body is taken into account when measuring the efficiency of body processes.

The basic unit of heat energy is the calorie (cal), defined as the amount of heat required to raise 1 gram (g) of water 1° C (1.8° F). This unit is too small for convenient use in nutrition. Thus, the *large Calorie*, the amount of heat required to raise 1 kilogram (1 kg = 1,000 g) of water 1° C (1.8° F), came into use and is written with a capital C and abbreviated Cal to distinguish from cal. Today, the term Calorie has been replaced by kilocalorie (kcal), which has the same value. Where larger values are involved, the megacalorie (megacal or Mcal), representing 1,000 kcal, is used. The Mcal is routinely used in ruminant and nonruminant nutrition.

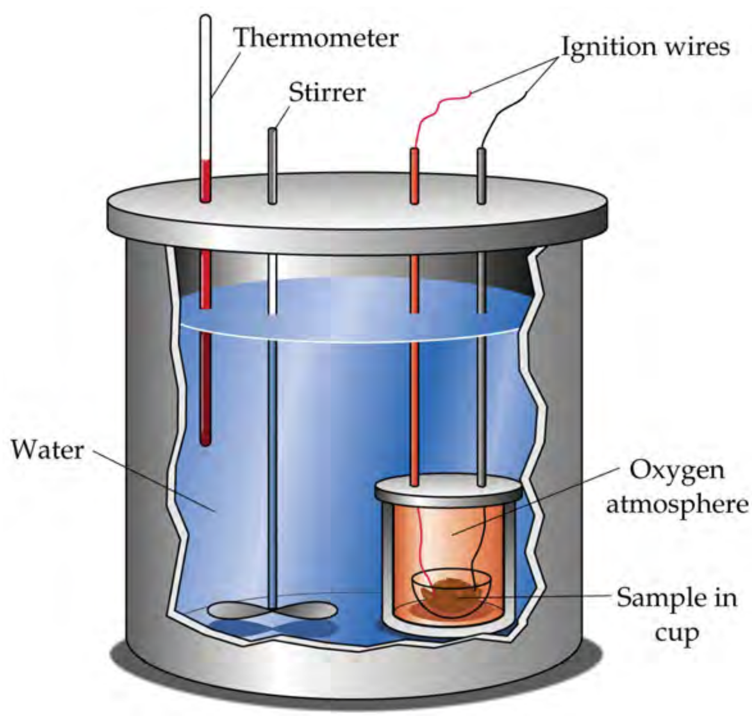

Figure 1. Bomb Calorimeter
Source: http://wps.prenhall.com/wps/media/objects/602/616516/Media_Assets/Chapter08/Text_Images/FG08_09.JPG

It has been more than 100 years since animal nutritionists discovered that feedstuffs CAN have the same amount of energy, but differ in their ability to produce growth, milk, wool, and work. Although nutritionists back then didn't have our modern computerized tools, they were able to measure the total energy of a feedstuff or diet with a piece of equipment called the *bomb calorimeter* (Figure 1). These scientists immersed a steel cylinder in a container of water. Then, they weighed a small feedstuff or diet sample, placed it at the bottom of the cylinder and burned it with an electronic ignition. All the sample's organic matter would burn completely in seconds, leaving a small pile of ash. The resulting heat caused a slight increase in the temperature of the surrounding water, allowing the scientists to convert the rise in temperature to calories. This was the **Gross Energy** of the sample. From this, we have progressed from a feedstuff or diet having one energy value until today when the same feedstuff or diet has four energy values (Gross, Digestible, Metabolizable, and Net).

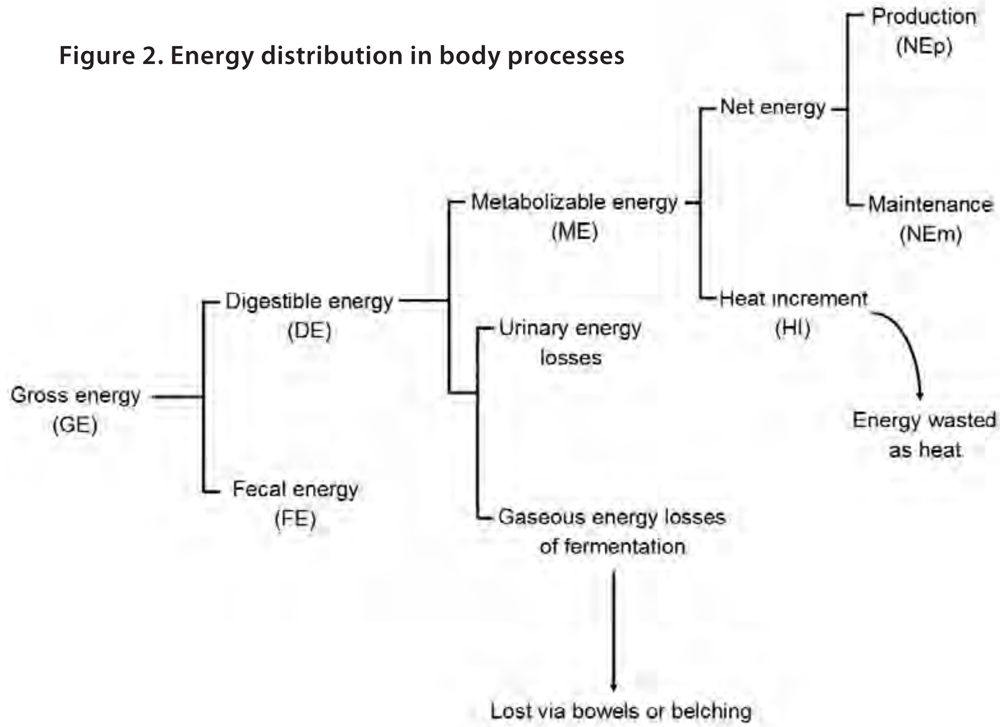

Figure 2. Energy distribution in body processes

Gross Energy

A measure of the energy contained in a feedstuff, from the bomb calorimeter and before it is consumed, is called **Gross Energy (GE)**. This is the total number of calories in the feedstuff. This is the number that is given to every feedstuff fed to livestock. But, the GE value is not very useful because it tells us nothing about the biological availability of the calories contained within. When samples are burned in a bomb calorimeter, all carbohydrates (sugar, starch, cellulose) give the same GE value (4 Calories/gram). All proteins give 5 Calories/gram and fats give 9 Calories/gram. Thus, GE does not differentiate among the *nutritional* values of sugar, cardboard boxes, or tree limbs.

Digestible Energy

In the late 1800s, livestock nutritionists found that they could burn a sample of feces in the calorimeter and when they did they found it contained some calories. So, they reasoned that any calories in the feces could have passed through the digestive tract without being absorbed. By subtracting the energy value of the feces from the energy consumed, they calculated the amount of energy that was absorbed (digested) from the digestive tract into the blood to be used for productive purposes. This was called **Digestible Energy (DE)**. Figure 2 shows how subtraction of fecal energy from GE equals DE. Although the early nutritionists were creative, modern-day nutritionists realize that consumed energy is not 100% digestible. These modern-day nutritionists have found that fecal energy may contain, in addition to undigested energy, sloughed cells from the digestive tract walls, bacteria, and enzymes that may have been involved in digestion of carbohydrates, proteins, and fats as they passed through the digestive tract.

Today, DE is still one of the most useful values in livestock nutrition. It often goes by different names like Digestive Organic Matter (DOM), Digestible Dry Matter (DDM), and Total Digestible Nutrients (TDN). Even though DE is the useful GE in a feedstuff, some of the calories of GE can be lost in more ways than in the feces. Two other routes are *gas* and *urine* (Figure 2).

Metabolizable Energy

All livestock lose some feedstuff energy as gas. Sheep, cattle, and goats make a livelihood of it because of the fermentation that takes place in the rumen. The two major products of rumen fermentation are methane and carbon dioxide. These are lost from the animal via bowels or belching (Figure 2).

The second loss, urine, contains energy in the soluble compounds flushed out during urination. The main soluble compound is *urea*. Although these calories may have been cycled through the liver and kidneys enroute to the urine. Once they are captured in urea, they are not used for growth, wool, milk, or heat. Therefore, they represent a loss to the animal.

Subtraction of the urine and gas losses from DE give us another term: **Metabolizable Energy (ME)**. More precisely, ME is the energy value of a

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feedstuff after subtracting the energy lost in the feces, gas, and urine (Figure 2). ME is always smaller than DE which is always smaller than GE because each term reflects subtraction of more and more calories that are lost to the animal.

Net Energy

Livestock still can't use all the calories in ME. Because they are warm-blooded, they produce heat from feedstuffs to stay warm and this requires energy (*heat increment;* Figure 2). But, energy used for heat can't be used to create meat, milk, or wool. So, NE calories are those available for tissue production (i.e., the net amount of energy in a feedstuff) after all the caloric losses in feces, gas, urine, and heat are accounted for (Figure 2).

Over the past 30 years, NE has spawned a whole family of related terms based on the way it is used. Some NE calories are used for making milk, wool, and meat (NEp; Figure 2), while others are reserved for maintaining the basic functions of the body like breathing, walking, eating, etc. (NEm). These terms now allow nutritionists to allocate precise amounts of energy to different types of production.

Application

Dietary carbohydrates, excess protein, and fats contribute toward fulfilling the energy requirements of sheep. Carbohydrates are the major sources. Concentrates (grains) contain starch, a rich source of energy. Roughages (hay, grazed forages, silage) contain fiber (cellulose). They are not as rich in energy as concentrates, but the fiber contained within is used to provide energy via ruminal microbial fermentation processes.

Quantitatively, energy is the most important nutrient in the sheep's diet. Optimal energy intakes from grazed forages, hay, silage, and grains result in efficient reproduction, growth, lactation, and wool production. However, excessive energy consumption leads to decreased efficiency because of excessive fattening, which reduces growth rate, lowers milk production, increases reproductive failure, and decreases efficiency of wool growth.

Energy can also be the most common limiting nutrient in sheep production, especially for ewes. This situation usually arises from an inadequate intake of feed resulting from drought, snow cover, low dry matter intake of green pasture or silage,

Table 1. Energy Requirements for the Annual Production Phases of a 154-lb Ewe[a]

Production Phase	DE, Mcal/d[b]	ME, Mcal/d[b]
Maintenance	2.9	2.4
Flushing	4.7	3.8
Early Gestation	3.4	2.8
Late Gestation	5.4	4.4
Early Lactation[c]	8.0	6.6

[a] Sheep Production Handbook. 2002. Volume 7, page 716. American Sheep Industry Association, Inc.
[b] DE, Mcal/d = Digestible Energy, Megacalories/day; ME, Mcal/d = Metabolizable Energy, Megacalories/day
[c] First 60 days, nursing twins

Table 2. Digestible and Metabolizable Energy Composition of Alfalfa Hay, Orchardgrass Hay, and Shelled Corn

Feedstuff	DE, Mcal/lb DM[a]	ME, Mcal/lb DM[a]
Alfalfa Hay, Earlybloom	1.20	0.99
Orchardgrass hay, Midbloom	1.14	0.94
Shelled Corn	1.80	1.48

[a] DE, Mcal/lb DM = Digestible Energy, Megacalories/lb dry matter; ME, Mcal/lb DM = Metabolizable Energy, Megacalories/lb dry matter

Table 3. Example Daily Ration That Meets the Digestible and Metabolizable Energy Requirements of 154-lb Ewes in Late Gestation (Expecting Twins)

Late Gestation	Lb/hd/d	DE, Mcal/d[a]	ME, Mcal/d[a]
Orchardgrass Hay, Midbloom	3.7	3.8	3.1
Shelled Corn	1.0	1.6	1.3
Total	4.7	5.4	4.4
Requirement	4.7	5.4	4.4
Difference	0	0	0

[a] DE = Digestible Energy (Megacalories); ME = Metabolizable Energy (Megacalories) consumed per ewe per day from 3.7 lb orchardgrass hay and 1.0 lb shelled corn.

Table 4. Example Daily Ration That Meets the Digestible and Metabolizable Energy Requirements of 154-lb Ewes in First 8 Weeks of Lactation (Suckling Twins).

Lactation	Lb/hd/d	DE, Mcal/d[a]	ME, Mcal/d[a]
Alfalfa Hay, Earlybloom	5.0	5.5	4.5
Shelled Corn	1.6	2.5	2.1
Total	6.6	8.0	6.6
Requirement	6.9	8.0	6.6
Difference	- 0.3	0	0

[a] DE = Digestible Energy (Megacalories); ME = Metabolizable Energy (Megacalories) consumed per ewe per day from 5.0 lb alfalfa hay and 1.6 lb shelled corn.

consumption of low-quality feedstuffs, or long-term access to unpalatable feedstuffs. Ewes carrying multiple fetuses in late gestation are likely candidates for an energy deficiency. Inadequate energy intake causes slow growth, weight loss, reproductive failure, decreased milk production, lowered resistance to diseases and parasites, and increased lamb and ewe mortality. Although energy requirements of ewes vary dramatically throughout the annual production cycle, energy intakes required during late gestation (LG) and lactation (L) are much higher than other stages of production. The most applicable forms of energy used to balance most sheep diets are DE and ME. Table 1 shows how these requirements vary during the year for ewes that weigh about 150 lb when open and nonlactating. The DE and ME composition of hays and shelled corn that are commonly fed during LG and L are shown in Table 2. Shelled corn contains more DE and ME, followed by alfalfa and orchardgrass hays. The composition of these feedstuffs and the nutrient requirements of ewes (Table 1) should give us some insight into which should be fed in LG and L. Requirements are highest in L followed by LG. Therefore, the feedstuffs with the highest concentrations of DE and ME should be fed in greatest amounts in L. The next highest concentrations and amounts should be fed in LG.

A daily ration of 3.7 lb orchardgrass hay and 1.0 lb shelled corn (Table 3) will meet the DE and ME requirements of 154-lb ewes carrying twins in LG. The energy contained in their daily ration will maintain her daily functions (breathing, walking, eating, etc.), provide energy for wool and fetal growth, and provide energy for colostrum (milk) synthesis. Feeding a ration with more hay and/or corn will cause ewes to become too fat for optimum production. In contrast, feeding less hay and/or corn will cause ewes to become too thin for optimum production.

A comparison of the LG (Table 3) and L diets (Table 4) shows the DE and ME requirements are greater in L, more hay and more corn are required to meet the DE and ME requirements of L, and the hay fed in L must be higher quality than that of LG. Even though there is a slight deficiency in pounds fed per day in L (Table 4), this is not a concern because the DE and ME daily requirements can be met by feeding 5.0 lb alfalfa hay (early bloom) and 1.6 lb shelled corn.

Summary

The Gross Energy of feedstuffs is a measure of the total energy contained within. Feedstuffs vary in their digestibility, so Digestible Energy is a more definitive measure of the "useable" energy. Still, some of the Digestible Energy may not be used completely for meat, milk, and wool production because some energy is lost to the animal via urine and gas. Metabolizable Energy is a more precise measure of the useful energy contained in the Gross Energy of feedstuffs. Sheep must consume a certain level of Digestible and Metabolizable energy each day if they are to maintain themselves (breathe, walk, eat), gain weight, produce milk, and/or produce wool. It is the shepherds' responsibility to provide a combination of energy feed sources in the proportions that will allow their animals to perform to their optimum. Then, we will know "What This Stuff We Call Energy" really is.

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