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# MEASURING THE DIGESTIBLE ENERGY CONTENT OF HORSE FEEDS

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One of the most important measures of a horse feed's value is its energy content. Energy density determines how much feed must be fed to meet an animal's energy requirement. Level of intake in turn dictates the concentration of all other nutrients in the feed. Therefore, horse feeds cannot be properly formulated without knowledge of their energy contents. Unfortunately, it is not possible to directly measure the amount of useful energy contained in feed as you can with other nutrients such as protein and minerals. Instead, energy content must be estimated from other measurements.

In the United States, the energy content of horse feed is expressed as Digestible Energy (DE). There are several different ways that DE content can be estimated and this has led to a great deal of confusion about how much DE is actually in horse feed. This paper will review the various methods that are used to measure digestible energy and provide guidelines about how to accurately estimate DE from easily measurable constituents in feed.

## Heat of combustion (gross energy)

When a substance is completely burned to its ultimate oxidation products (carbon dioxide, water and other gases), the heat given off is considered its gross energy or heat of combustion. This measure is the starting point in determining the energy value of feed. The determination is usually carried out in a bomb calorimeter. The bomb calorimeter consists of a bomb in which the feed is burned, enclosed in an insulated jacket containing water which surrounds the bomb and which thus provides the means of measuring heat production. The basic unit of heat energy is the calorie (cal), defined as the amount of heat required to raise 1 g of water $1^{\circ}C$, measured from 14.5 to $15.5^{\circ}C$. This unit is too small for use in horses, so the energy content of horse feed is usually expressed as kilocalories (kcal) or megacalories (Mcal). There are 1000 calories in a kcal and 1,000,000 calories in a Mcal. Measured in terms of the joule, the international unit of work and energy, 1 Mcal = 4.185 megajoules (MJ).

Table 1 contains the gross energy content of a number of pure substances and horse feeds. As you can see, fats contain over twice as much gross energy as carbohydrates. These differences are due to the relative amount of oxygen contained

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in each molecule, since heat is produced only from the oxidation which results from the union with oxygen from outside the molecule. In the case of carbohydrates, there is enough oxygen present in the molecule to take care of all the hydrogen present, and thus heat arises only from the oxidation of the carbon. In the case of fat, however, there is much less oxygen present and the combustion involves the oxidation of hydrogen as well as carbon.

The difference in gross energy between glucose and starch is because there is relatively more carbon in 1 g of starch than in 1 g of glucose and thus starch has a higher energy value.

The energy producing component of horse feed can be divided into three classes of nutrients: protein, fat, and carbohydrates. These three classes of nutrients typically have the following gross energy contents:

| | |
|---|---|
| Carbohydrates | 4.15 kcal/g |
| Fats | 9.40 kcal/g |
| Proteins | 5.65 kcal/g |

These gross energy values for the three classes of nutrients explain the gross energy (GE) differences in the feeds listed in table 1. Oats have more GE than corn because they contain more protein and fat. Whole soybeans are high in protein and fat, so their GE is even higher.

**Table 1.** GROSS ENERGY VALUES OF PURE SUBSTANCES AND FEEDS (DRY MATTER BASIS)

| *Pure substance* | *Gross Energy (kcl/g)* | *Feed* | *Gross Energy (kcal/g)* |
|---|---|---|---|
| Glucose | 3.76 | Corn | 4.43 |
| Starch | 4.23 | Oats | 4.68 |
| Seed fat | 9.23 | Soybeans | 5.52 |
| Lard | 9.48 | Timothy hay | 4.51 |
| Casein | 5.86 | Oat straw | 4.43 |

## Digestible energy (DE)

It should be obvious from table 1 that GE is a poor indicator of overall feed value since the GE of corn is identical to the GE of oat straw. Gross energy does not differentiate between various carbohydrate sources and starch and cellulose contain the same GE content. Therefore, to be useful as an indicator of productive energy, losses of energy must be accounted for. The first and largest loss of gross energy occurs in digestion. By determining the heat of combustion of the feces and subtracting this value from the GE, one obtains digestible energy (DE). Table 2 shows the results of a digestion trial in which the DE of three different feeds were determined (Pagan,

1982).

The GE of these diets was related to their composition. Diet 1 which contained the most starch and least protein had the lowest GE. Its digestibility, however, was highest and it consequently contained the most DE. This type of digestion trial is an accurate method to determine DE in the total diet, but it has two serious drawbacks. First, it is simply not practical to measure the DE content of every horse ration, since conducting a digestion trial is laborious and expensive. Secondly, measuring the GE of feces does not determine the DE of each individual feed, but rather the overall digestibility of the entire ration.

**Table 2.** DIGESTION TRIAL WITH 3 DIFFERENT FEEDS

| Diet number | Alfalfa % | Corn % | Soybean meal % | GE feed (kcal/g) | GE feces (kcal/g) | DM digestibility | Digestible Energy (kcal/g) |
|---|---|---|---|---|---|---|---|
| 1 | 34 | 63 | 3 | 4.45 | 4.96 | 80.8 | 3.54 |
| 2 | 40 | 53 | 7 | 4.52 | 4.92 | 78.6 | 3.47 |
| 3 | 47 | 37 | 16 | 4.56 | 5.01 | 76.2 | 3.37 |

## Total digestible nutrients (TDN)

Digestible energy can be estimated by first measuring the total digestible nutrient (TDN) content of the feed. TDN is calculated as: digestible crude protein (CP) + (digestible crude fat (EE) x 2.25) + digestible cell wall (NDF) + digestible non structural carbohydrate (NSC). Non structural carbohydrate = 100-CP-EE-NDF-ash. Fonnesbeck (1981) conducted 108 digestion trials with horses and measured both TDN and DE. The relationship between TDN and DE was best described as DE (kcal/kg) = 255 + 3660 x TDN.

## Estimating DE from chemical composition

There are a number of ways that DE can be estimated for a feed using its chemical composition. One method is to determine the DE content of a large number of different rations and statistically relate the DE content to other components of the feed. At our laboratory we have conducted dozens of digestibility studies with a wide range of feedstuffs. From data with 30 different diets (120 observations) , we have developed a regression equation to predict DE from chemical composition. The rations studied ranged from pure alfalfa hay to a combination of sweet feed and fescue hay to pelleted concentrates fed with timothy hay.

The energy content of the various rations was calculated as percent total digestible nutrients (TDN %) and converted to DE using Fonnesbeck's equation.

The most complete equation to estimate DE from these data was:

DE (kcal/kg DM) = 2,118 + 12.18 (CP%) - 9.37 (ADF %) -3.83 (hemicellulose %) + 47.18 (fat %) + 20.35 (NSC) - 26.3 (ash %) ($R^2$=0.88).

Notice that as protein, fat and NSC increase, DE increases. As fiber and ash increase, DE decreases. This is because the digestibility of protein, fat and NSC tends to be quite high (>85%) while the digestibility of fiber tends to be lower (~40-45%) in most feeds. Ash doesn't contain any energy, so it would naturally lower the overall energy density of a feed.

KER also uses another method of determining the digestibility of individual feed ingredients. In this design, a basal ration of forage cubes is fed to horses and its digestibility content is measured. Individual feeds are then fed along with the forage and the overall digestibility is measured. By difference, the digestibility of the individual ingredient is determined. The digestibility of each organic component (protein, fat, NSC, and NDF) is multiplied by its heat of combustion to calculate DE content. It could be argued that feeding another ingredient along with the forage may change the digestibility of the forage. Even if this is true and the change in digestibility is credited to (or debited from) the ingredient, the overall estimate of digestibility is correct since these ingredients are always fed with some type of forage.

**Table 3.** DE content of several different common horse feed ingredients calculated by a number of different methods (as fed basis).

| Feed | NRC (Mcal/lb) | KER Regression (Mcal/lb) | KER Regression %NRC | Direct Measurement (Mcal/lb) | Direct Measurement %KER Equation | Direct Measurement % NRC |
|---|---|---|---|---|---|---|
| Oats | 1.30 | 1.33 | 102.3 | 1.33 | 100 | 102.3 |
| Corn | 1.54 | 1.53 | 99.3 | 1.58 | 103.3 | 102.3 |
| Wheat Midds | 1.38 | 1.20 | 87.0 | 1.26 | 105.0 | 91.3 |
| Molasses | 1.18 | 1.17 | 99.2 | 1.20 | 102.5 | 101.7 |
| Alfalfa Hay | 0.94 | 0.96 | 102.1 | 1.0 | 104.2 | 106.4 |
| Timothy Hay | 0.80 | 0.86 | 107.5 | 0.85 | 98.8 | 110.0 |
| Rice Bran | 1.19 | 1.23 | 103.4 | 1.44 | 117.0 | 121.0 |
| Beet Pulp | 1.06 | 1.08 | 101.9 | 1.28 | 118.5 | 120.7 |
| Soy Hulls | 0.77 | 0.82 | 106.5 | 1.17 | 142.7 | 151.9 |
| Oat Hulls | 0.65 | 0.79 | 121.5 | 0.51 | 64.6 | 78.5 |

KER's regression equation using data from the 30 different rations produces DE values which were very close to the NRC estimates for most of the feeds measured. Only wheat midds and oat hulls differed substantially from the NRC estimates (table 3).

The direct measurements of digestibility confirm that both the NRC and the KER equation accurately describe the DE content of cereal grains and hays. Both, however, grossly underestimate the DE content of high fat feeds (rice bran) and non-forage, high fiber feeds such as beet pulp and soy hulls. Both also overestimate the digestibility of poor quality fiber sources like oat hulls.

The fat from feed ingredients that contain high levels of fat is more digestible than fat found in forages and cereal grains. An equation based on diets that are fairly low in fat will tend to underestimate the energy contribution from high fat feeds. The KER equation was developed with rations ranging in fat content from 2.1% to 5.5%, so an allowance should be made for high fat feeds. If a feed contains more than 5% fat, add an extra 0.02 Mcal/lb (0.044 Mcal/kg or 0.18 MJ/kg) for each 1% fat over 5%. For example, the rice bran in the above example contains 15% fat, so 0.2 Mcal/lb (10% x 0.02 Mcal/lb) should be added to the DE calculated from the KER equation. This would yield 1.43 Mcal/lb (1.23 + 0.2) which is very close to the DE measured directly (1.44 Mcal/lb).

Both the NRC and KER equation underestimate the DE content of beet pulp and soy hulls. This is because the cell wall of these two ingredients is much more digestible than the cell wall found in most horse feeds. Likewise, the cell wall in oat hulls is less digestible than most forages and allowances should be made for this in calculating DE. The same is true for other poorly digestible fiber sources such as peanut hulls and rice hulls.

## DE in grain mixes

There is a great deal of variation in the reported DE contents of various horse feeds. Some manufacturers routinely overestimate the DE content of their feeds and use these exaggerations to promote their product. In reality, the DE content of a grain mix can only be altered to a relatively small degree unless large amounts of fat or fiber are added. Let's examine an example of how composition affects DE. A simple grain mix of 40% oats, 40% corn, 10% molasses and 10% soybean meal would contain about 14% protein, 3.4% fat and 14% NDF. This mix would contain around 1,440 kcal/lb of DE. Adding 1% vegetable oil to the mix would only elevate the DE by 30 kcal/lb, so this mix would contain 4.4% fat and 1,470 kcal/lb. To reach a DE of 1,600 kcal/lb, 6% oil would need to be added to the diet and the total fat content of the feed would approach 10%. Manufacturers who claim that their 4-5 % fat feeds contain 1,600

kcal/lb need to recheck their figures (table 4).

**Table 4.** DE AND TOTAL FAT WITH DIFFERENT LEVELS OF ADDED FAT[1]

| | *0%* | *1%* | *2%* | *3%* | *4%* | *5%* | *6%* | *7%* |
|---|---|---|---|---|---|---|---|---|
| | *% added fat* | | | | | | | |
| Total fat (%) | 3.4 | 4.4 | 5.4 | 6.3 | 7.3 | 8.3 | 9.2 | 10.2 |
| DE (kcal/lb) | 1,440 | 1,470 | 1,490 | 1,520 | 1,550 | 1,570 | 1,600 | 1,620 |

[1] 14% protein grain mix containing 40% corn, 40% oats, 10% molasses, and 10% soybean meal.

## Conclusions

The Digestible Energy (DE) content of most horse feeds can be estimated from a regression equation developed by KER that uses the crude protein, crude fat, ADF, hemicellulose (NDF-ADF), non-structural carbohydrate (NSC) and ash content of feed. This equation works well for most horse feeds except those that contain high levels of fat or that contain fiber which is either much more or less digestible than forage. A correction of 0.02 Mcal DE/lb should be applied for every 1% fat over 5% in a feed. Beet pulp and soy hulls contain highly digestible fiber and their DE contents are 20-50% higher than suggested by the NRC. Oat hulls have very poorly digestible fiber and DE values that are only 80% of NRC estimates.

Many manufacturers overestimate the DE content of their feeds. A typical grain mix without added fat will contain around 1,400-1,450 kcal/lb. A feed with 6% added fat and a total fat content of around 10% will contain around 1,600 kcal/lb. Feed manufacturers should review the DE values that they currently use in formulating horse feeds to insure that reasonable DE values are assigned to their feed ingredients.

## References

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