# Nutritional data

## Energy values

### Basis

Animals use the gross energy (GE) contained in the organic matter (OM) of ingested feeds according to a general scheme identical for all species (figure 1).

The best system to express the feed energy content is net energy (NE). In order to calculate NE, it is necessary to start with the GE value and predict sequentially the values of energy digestibility as well as the energy lost in the form of methane, urine and heat increment.

### Gross energy

Gross energy is measured by calorimetry. It can also be predicted from the chemical composition using a coefficient for each constituent and different models can be used. For the tables, we have tried to base the prediction equations on the common and readily available measurements of the proximate analysis. A statistical analysis performed on more than 2000 gross energy values resulted in the following equation:

$$GE = 17.3 + 0.0617\ CP + 0.2193\ EE + 0.0387\ CF - 0.1867\ Ash + \Delta$$

GE is gross energy expressed in MJ/kg of dry matter; CP, EE, CF and Ash represent crude protein, ether extract, crude fibre and minerals respectively, expressed in % dry matter.

$\Delta$: correction coefficient (positive or negative) to be used according to the type of feed material. Several statistical analyses were conducted in order to optimise the determination of $\Delta$ (Tran and Sauvant, unpublished). The following table presents the specific $\Delta$ values for different groups of feed materials.

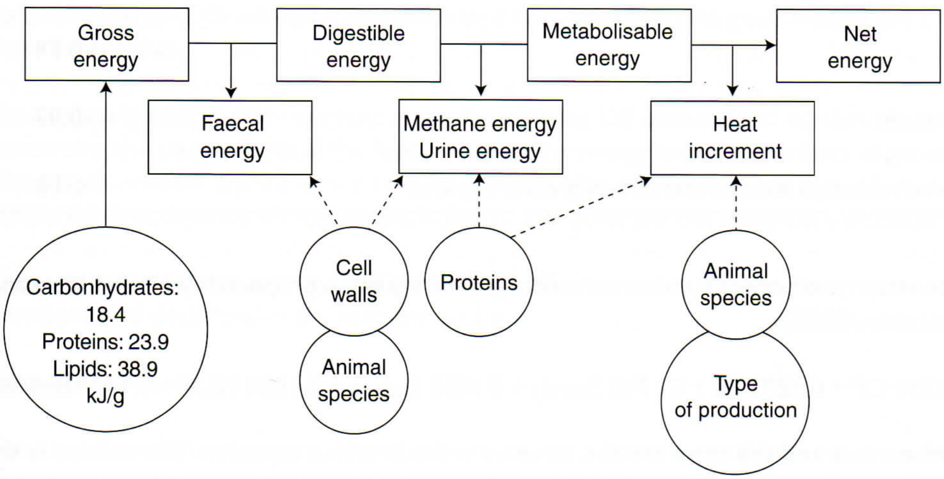


**Figure 1.** The different steps in feed energy utilisation.

| Feed material group | Δ |
|---|---|
| Corn gluten meal | 1.29 |
| Blood meal | 1.12 |
| Alfalfa protein concentrate | 1.04 |
| Wheat distillery by-product, wheat gluten feed, maize bran, rice bran | 0.58 |
| Full fat rapeseed, full fat linseed, full-fat cottonseed, cottonseed meal | 0.49 |
| Oats, wheat milling by-products, corn gluten feed and other maize starch by-products, maize feed flour, sorghum | 0.31 |
| Dehydrated grass, straw | 0.19 |
| Barley | 0.15 |
| Barley rootlets, meat and bone meal | -0.18 |
| Linseed meal, palm kernel meal, full fat soybean, soybean meal, sunflower meal, sunflower seed | -0.19 |
| Cassava | -0.23 |
| Faba bean, lupin, pea | -0.36 |
| Sugar beet pulp, molasses, vinasse, potato pulp | -0.43 |
| Whey | -0.74 |
| Soybean hulls | -0.97 |
| Other feed materials except starch and brewer's grains | 0.00 |

For maize starch and brewer's grains, we used a general equation proposed by Noblet (personal communication, 2002):

$$GE = 0.2299\ CP + 0.3893\ EE + 0.1740\ Starch + 0.1655\ Sugars + 0.1884\ NDF + 0.1773\ Residue$$

The abbreviations and the units are the same as in the previous equation. The residue is the difference between organic matter and the sum of the other constituents in the equation.

# Nutritional values for ruminants

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## Digestibility and energy value

### Source of data and harmonisation of digestibility values

The digestibility and energy values for ruminants presented in the tables have been established using a database of digestibility measurements obtained *in vivo* on more than 300 feed samples studied by INRA (France) and by the Rowett Research Institute (United Kingdom).

Since the digestibilities of organic matter (OMd), dry matter (DMd) or energy (Ed) were not available simultaneously for every feed sample, it was necessary to work on a unique parameter: OMd was present for 89% of the samples and the missing OMd values were calculated by regression equations using Ed or DMd as predictors. These equations integrated additional analytical characteristics when they were statistically significant.

### Calculation of organic matter digestibility values for feed materials

With OMd values available for each feed material, we studied prediction models based on cell wall parameters (crude fibre, NDF, ADF) for this digestibility. Many of the resulting equations have crude fibre as the main predictor, as this parameter was the most frequent cell wall criterion in the database.

Regressions integrating discriminating tests between groups of feed materials within the same relationship were calculated by variance-covariance analysis. Interactions between the predictor and the groups were also tested in order to identify the possible effects of the type or family of feed materials on the regression slope. Therefore, six major prediction models concerning the following groups of ingredients were calculated.

*Cereal grains and cereal by-products*

$OMd = 95.81 - 1.911\ CF + \alpha$ (n = 124; r = 0.93; RSD = 3.7)

Where $\alpha = -2.54$ all feed materials except maize by-products

$\alpha = +2.54$ maize by-products

*Full fat rapeseed, full fat sunflower, full fat cottonseed, copra meal, palm kernel meal and cottonseed meal*

$OMd = 97.51 - 1.498\ CF$ (n = 29; r = 0.79; RSD = 6.5)

*Legume and oil seeds, groundnut meal and soybean meal*

$OMd = 87.75 - 0.314\ CF + \alpha$ (n = 46; r = 0.74; RSD = 3.8)

Where $\alpha = -4.36$ full fat soybeans

$\alpha = -1.86$ groundnut meal

$\alpha = +6.2$ other legume and oil seeds, soybean meal

*Sugar beet pulp and citrus pulp*
Sugar beet pulp:

$$OMd = 87.20 - 0.951\ (CF - 16.39)$$

Citrus pulp:

$$OMd = 84.11 - 1.374\ (CF - 16.39)$$

For the two groups: $n = 34$; $r = 0.86$; $RSD = 2.0$

*Cassava, molasses, vinasse and potatoes*
$OMd = 97.81 - 1.12\ NDF$ ($n = 5$; $r = 0.98$; $RSD = 2.6$)

*Dehydrated forages*
Alfalfa:

$$OMd = 65.90 - 0.919\ (ADF - 29.83)$$

Grasses:

$$OMd = 74.13 - 1.364\ (ADF - 29.83)$$

For the two groups: $n = 32$; $r = 0.86$; $RSD = 3.6$

In these equations, CF (crude fibre), NDF and ADF are expressed in % dry matter and OMd in %.

The residual standard deviations for these equations were between 2 and 4% of OMd. The equations were then applied to the chemical composition of the feed materials presented in the tables. With this method, we obtained consistent values for OMd for more than 85% of the feed materials. In the case of some rarely used by-products, no recent data of *in vivo* digestibility were available, and we derived their digestibility values from the tables of Becker and Nehring (1965), an old but well-documented source of feed information.

## Calculation of energy values

The calculations of energy values were performed using the approach and the equations proposed by INRA (INRA, 1978; INRA, 1988; Vermorel *et al.*, 1987). UFL and UFV values were calculated for each feed material in the tables: UFL (Unité Fourragère Lait, feed unit for milk production) is the energy unit for lactating ruminants or slow growing ruminants; UFV (Unité Fourragère Viande, feed unit for meat production) is the energy unit for medium to fast growing ruminants. One UF corresponds to the energy value of a kilogramme of standard barley.

*Energy digestibility (Ed)*

Ed was calculated from OMd and chemical components using regression equations obtained from the database cited above:

$$Ed = OMd - 3.94 + 0.104\ CP + 0.149\ EE + 0.022\ NDF - 0.244\ Ash$$

(n = 183; r = 0.68; RSD = 1.5)

$$Ed = OMd - 3.50 + 0.046\ CP + 0.155\ EE$$ (n = 216; r = 0.35; RSD = 1.8)

$$Ed = OMd - 2.90 + 0.051\ CP$$ (n = 250; r = 0.35; RSD = 2.0)

Ed and OMd are expressed in %; the chemical constituents (CP: crude protein; EE: ether extract; Ash: minerals) are expressed in % dry matter.

The choice between the different equations is based on the availability of analytical data and the most precise equation should be used.

*Digestible and metabolisable energy levels*

Digestible energy: DE = GE x Ed / 100

Metabolisable energy: $ME = DE \times \frac{ME}{DE}$

$100\ ME / DE = 86.38 - 0.099\ CFo - 0.196\ CPo$

GE: gross energy in MJ/kg dry matter; CFo: crude fibre in % of organic matter; CPo: crude protein in % of organic matter.

Metabolisable energy concentration of the feed: $q = \frac{ME}{GE}$ $(0 < q < 1)$

The coefficient q is used in the equations below.

*Efficiency of utilisation of metabolisable energy for net energy*

The coefficients kl, km and kf are comprised between 0 and 1.

For lactation: $kl = 0.60 + 0.24\ (q - 0.57)$

For maintenance: $km = 0.287\ q + 0.554$

For fattening: $kf = 0.78\ q + 0.006$

For maintenance and meat production: $kmf = \frac{km \times kf \times 1.5}{kf + 0.5 \times km}$

*UFL and UFV values*

UFL value = $\frac{ME \times kl}{7.12}$

UFV value = $\frac{ME \times kmf}{7.62}$

The NE values of the reference barley were kept at 7.12 and 7.62 MJ/kg for milk and meat production respectively, even though the most recent NE values for average barley are 6.76 and 7.08 MJ/kg as fed respectively.