Prediction of the net energy value of broiler diets

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(Received 6 February 2013; Accepted 1 May 2014; First published online 6 June 2014)

Thirty pelleted diets were given to broiler chickens (eight birds per diet; 21 to 35 days of age) for individual in vivo measurements of dietary net energy (NE) value, using three trials with 10 diets/trial. Amino acid formulation of diets was done on the basis of ratios to CP. NE was measured according to the body analysis method. The basal metabolism component of NE values was calculated on the basis of mean metabolic weight using a coefficient obtained in a previous experiment. Information about apparent metabolisable energy (AME) value of diets, AME corrected to zero nitrogen retention (AMEn) and digestibilities of proteins, lipids, starch and sugars was available from a previous publication. In each trial, mean NE/AME ratios of diets varied by about 6%. From the multiple regressions (n = 30) expressing NE and AMEn values as functions of digestible component contents, it was deduced that the NE/AMEn ratios assigned to dietary components were 0.760, 0.862, 0.806, 0.690 and 0.602 for CP, lipids, starch, (sucrose + glucose) and fermentable sugars (α-galacto-oligosaccharides and lactose), respectively. The NE/AME ratio of CP was 0.680. Regression calculations showed that the NE values assigned to individual birds (n = 240) could also be predicted with diet AMEn values (NE = 0.80 AMEn; R2 = 0.770) or with an equation combining AMEn value and CP/AMEn ratio (R2 = 0.773). The latter ratio was found to be the only additional parameter that was significant when added in the NE regression scheme based on AMEn.

Keywords: chicken, dietary energy, NE, ME, AME

Implications
The study supplies methods for calculating the net energy value of broiler diets and feedstuffs to be used by feed manufacturers.

Introduction
The expression of energy value of diets as net energy (NE) is widely used in ruminant and pig nutrition, whereas the NE expression is practically never used in poultry. In poultry, dietary energy value is expressed as metabolisable energy (ME), which is preferred to digestible energy (DE) because, in birds, faeces and urinary losses are voided together through cloaca. In most cases, ME is expressed as apparent metabolisable energy (AME) corrected to zero nitrogen retention (AMEn).

Reviews on the efficiency of ME for NE in poultry were performed in 1974 by De Groote and in 1999 by Pirgozliev and Rose. It appears from these reviews that the number of studies devoted to NE calculation was much more limited in poultry than in ruminants or pigs. In ruminants or pigs, the interest in using NE instead of DE or ME comes from the fact that the NE/DE or NE/ME ratios are affected by the extent of fibre digestion (Jarrige, 1980; Just et al., 1983; Noblet et al., 1994). In poultry, the extent of fibre digestion is very low (Carré et al., 1990), which would decrease variations in NE/ME ratios and thus, would reduce the interest of an NE system.

We conducted a study in broiler chickens to supply reliable data allowing both AMEn and NE values to be predicted and evaluated, using 30 different diets. A first publication (Carré et al., 2013) reported in vivo measurements and predictions of AMEn values. In the current publication, in vivo measurements, calculations and predictions of NE values are reported using the same set of experimental data (Carré et al., 2013). NE values were determined with the method based on body analyses, measuring protein and lipid depositions from 21 to 35 days. The component of NE associated with maintenance was calculated on the basis of mean metabolic weight using a coefficient obtained in an experiment (Van Milgen et al., 2001; Noblet et al., 2010) conducted with birds from the same commercial strain.

Material and methods

Bird management
The experiment was conducted in 1996. AMEn and NE values of 30 diets were measured in male broiler chickens from 21 to 35 days of age. AMEn and NE determinations were

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carried in the same trials, but they were not measured in the same birds. Birds for measuring AMEn and NE values were placed in two different rooms having the same environmental conditions. Diets, bird management, housing system and results of AMEn data were previously reported (Carré et al., 2013). The whole experiment was divided into three successive trials at 4 weeks interval. In each trial, a total of 400 male broiler chickens (UV 915, ISA) were used. Among these 400 broiler chickens, 180 birds were selected at 21 days of age in order to obtain 20 groups of 8 birds homogeneous for their BW and a group of 20 birds showing similar mean BWs (680 g). This group of 20 birds was killed by cervical dislocation for measurement of initial body composition. Among the 20 other groups, 10 were used for measurements of NE and growth performances, each group being randomly allocated to a specific experimental diet. The last 10 groups received the same diets for measurements of AMEn and digestibilities (Carré et al., 2013). Each bird was placed at random in individual wire cages (44 cm length, 33 cm width and 50 cm height) supplied with individual feeder and drinker, in two environmentally controlled rooms (a room for ME and another for NE determinations), as previously described by Carré et al. (2013).

Measurements of NE values and growth performances
Each bird assigned to NE determination was weighed at the beginning (21 days) and the end of the experiment (35 days). Birds were ad libitum fed and individual feed intakes were measured on a feed dry matter (DM) basis. NE values were determined using the body analysis method. At 35 days, birds were killed by cervical dislocation, feathers were removed and weighed, feathers and carcasses were frozen (−20°C). Then, each frozen carcasses were first cut in small pieces with an electric band saw and ground with an electric table top meat grinder. Ground carcasses were freeze-dried and individually analysed for nitrogen (Kjeldahl method) and lipids, with no acidic treatment before the lipid extraction by petroleum ether (Carré et al., 2013). A pooled sample of feathers was also analysed for their nitrogen content. Total body nitrogen content was obtained by adding nitrogen from feathers and carcass. The 20 birds killed at 21 days were analysed in the same way. The relationships between body composition and BW measured at 21 days were used to evaluate the initial body composition of birds killed at 35 days. For each bird killed at 35 days, the lipid and nitrogen body accretions from 21 to 35 days were deduced from BW and body composition at 21 days and 35 days.

Diets
As previously reported (Carré et al., 2013), the 30 experimental diets were formulated in order to obtain independent variations of proteins, lipids, starch, available sugars (sucrose and glucose) and fermentable sugars (α-galacto-oligosaccharides and lactose). Calculated AMEn values (adult cockerel) ranged from 10.48 to 13.76 MJ/kg (as-fed) and calculated CP from 16.0% to 26.5% (as-fed). Diets differed between trials, except diets 11.1, 11.2 and 11.3 used in trial 1, 2 and 3, respectively. Diets were attributed to trials in such a way that similar mean diet compositions were obtained for each trial. Except for diet 26, amino acids were formulated on the basis of ratios to CP (Carré et al., 2013), not to ME, with the limiting amino acid being either lysine (minimum ratio to CP: 0.046) or sulphur amino acids (minimum ratio to CP: 0.035), which gave an ideal protein content of CP of about 70% for each diet. Diet 26, a low protein diet formulated as diet 6, was supplemented with pure amino acids on the basis of ratios to ME. All diets were distributed as pellets. Diets were analysed as previously described (Carré et al., 2013).

Calculations
The AME value of diets was the mean in vivo AMEn value previously measured (Carré et al., 2013), corrected by the addition of the urinary energy equivalent to the measured body nitrogen gain (0.0344 MJ/g nitrogen; Hill and Anderson, 1958) related to feed intake from 21 to 35 days. The coefficients expressing the gross energy value of body proteins (23.69 MJ/kg) and lipids (39.18 MJ/kg) were issued by Znaniecka (1967). The coefficient expressing the basal metabolism measured as the activity-free fasting heat production (0.50 MJ/kg BW^{0.60}/day) was obtained from a previous experiment (Van Milgen et al., 2001; Noblet et al., 2010) conducted in 2000 with broilers from the same genetic cross. The NE value of diets was calculated as follows for each bird, using individual data for each parameter of equation:

\[ NE(MJ/kg) = [14 \times 0.50(BW_1^{0.60} + BW_2^{0.60})/2 + 23.69PD + 39.18LD]/Fl_t \]

where 14 is the number of days, BW_1 the BW (kg) at 21 days, BW_2 the BW (kg) at 35 days, PD the protein deposition (kg) from 21 to 35 days, LD the lipid deposition (kg) from 21 to 35 days and Fl_t the total feed intake (kg) from 21 to 35 days.

Statistical analyses
Statistical analyses were performed using the SuperAnova software (1989 to 1991, version 1.11, Abacus Concepts Inc., Berkeley, CA, USA). The analyses testing the diet effect were conducted in 2000 with broilers from the same genetic cross. For regressions with no intercept, R^2 values were calculated as [1 – r.s.d.^2/\sigma^2_y], with r.s.d. and \sigma^2_y being the residual standard deviation of the regression equation and the variance of the dependent variable, respectively. Trial effects were estimated in regression calculations by adding trial effect in regression models with intercept; thereafter, the dependent variable was corrected according to the estimations of trial effect and the regression calculation was conducted again with the same scheme without including the trial effect.

Results
Table 1 shows the variations in energy values and contents of digestible components among the 30 diets. Mean NE and AMEn values displayed the same CV (0.078) and varied
Net energy prediction in broiler chickens

Table 1 Energy values1 and digestible component contents1 of diets (mean, s.d., minimum and maximum values for the 30 experimental diets) measured in broiler chickens (IJV 915, ISA)

<table>
<thead>
<tr>
<th>Component</th>
<th>Mean</th>
<th>s.d.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE (MJ/kg feed)</td>
<td>10.79</td>
<td>0.842</td>
<td>9.26</td>
<td>12.38</td>
</tr>
<tr>
<td>AME (MJ/kg feed)</td>
<td>14.13</td>
<td>1.056</td>
<td>12.03</td>
<td>15.62</td>
</tr>
<tr>
<td>NE/AME</td>
<td>0.764</td>
<td>0.0176</td>
<td>0.726</td>
<td>0.799</td>
</tr>
<tr>
<td>NE/AMEn</td>
<td>0.800</td>
<td>0.0190</td>
<td>0.756</td>
<td>0.839</td>
</tr>
<tr>
<td>DiCP3 (%)</td>
<td>19.0</td>
<td>2.75</td>
<td>14.9</td>
<td>25.8</td>
</tr>
<tr>
<td>DiL6 (%)</td>
<td>8.3</td>
<td>1.58</td>
<td>5.0</td>
<td>11.0</td>
</tr>
<tr>
<td>DiNCC7 (%)</td>
<td>42.7</td>
<td>4.28</td>
<td>31.2</td>
<td>49.6</td>
</tr>
<tr>
<td>DiStp8 (%)</td>
<td>37.3</td>
<td>4.11</td>
<td>26.5</td>
<td>43.7</td>
</tr>
<tr>
<td>DiStp10 (%)</td>
<td>36.7</td>
<td>4.37</td>
<td>26.3</td>
<td>44.1</td>
</tr>
<tr>
<td>DiSuc12 (%)</td>
<td>5.2</td>
<td>1.58</td>
<td>3.4</td>
<td>9.5</td>
</tr>
<tr>
<td>DiGlc11(%)</td>
<td>3.0</td>
<td>1.23</td>
<td>2.0</td>
<td>7.2</td>
</tr>
<tr>
<td>DiSuc12 (%)</td>
<td>1.9</td>
<td>1.01</td>
<td>1.0</td>
<td>5.6</td>
</tr>
<tr>
<td>Undetermined P13 (%)</td>
<td>0.2</td>
<td>0.94</td>
<td>-1.8</td>
<td>2.6</td>
</tr>
<tr>
<td>Undetermined E14 (%)</td>
<td>1.1</td>
<td>1.36</td>
<td>-2.1</td>
<td>4.5</td>
</tr>
</tbody>
</table>

1Data expressed on feed dry matter basis. AMEn values, crude component contents and digestibilities were shown for each diet in a previous publication (Carré et al., 2013).
2Net energy (NE) value of diets, measured with the body analysis method conducted from 21 to 35 days of age, with eight birds per diet (r.s.d. = 0.444).
3Apparent metabolisable energy value of diets calculated from AMEn by the addition of the urinary energy equivalent to the body nitrogen gain.
4AME corrected to zero nitrogen retention, measured (together with digestible proteins and digestible lipids) from 27 to 31 days of age. NE and AMEn experiments were conducted in the same time, but not with the same individual birds.
5Apparent digestible CP.
6Digestible lipids B (acidic treatment before extraction).
8Digestible starch P (Polarimetric method).
9Digestible starch E (DMSO-enzyme method).
10Digestible total sugars (reducing sugar method).
11Sucrose + glucose.
12Digestible fermentable sugars (lactose and α-galacto-oligosaccharides).

Table 2 Data used for NE calculations: BW, weight gain, protein and lipid depositions, and feed intakes in broilers from 21 to 35 days (3 trials, 30 different diets with 10 diets/trial and 8 broilers/diet; n = 240)

<table>
<thead>
<tr>
<th>Component</th>
<th>Mean</th>
<th>s.d.</th>
<th>Minimum</th>
<th>Maximum</th>
<th>r.s.d.</th>
<th>Trial effect1</th>
<th>Diet effect1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW at 21 days (g)</td>
<td>681</td>
<td>4.2</td>
<td>672</td>
<td>689</td>
<td>22.9</td>
<td>0.80</td>
<td>1</td>
</tr>
<tr>
<td>Total body protein</td>
<td>115.4</td>
<td>1.90</td>
<td>111.1</td>
<td>118.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total body lipids</td>
<td>80.1</td>
<td>0.92</td>
<td>78.1</td>
<td>81.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW at 35 days (g)</td>
<td>1643</td>
<td>57.4</td>
<td>1512</td>
<td>1747</td>
<td>79.7</td>
<td>0.34</td>
<td>0.0001</td>
</tr>
<tr>
<td>Daily weight gain</td>
<td>69.0</td>
<td>4.06</td>
<td>59.3</td>
<td>76.0</td>
<td>5.15</td>
<td>0.36</td>
<td>0.0001</td>
</tr>
<tr>
<td>Daily protein gain</td>
<td>13.6</td>
<td>1.02</td>
<td>10.6</td>
<td>15.3</td>
<td>0.92</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Daily lipid gain</td>
<td>11.0</td>
<td>1.66</td>
<td>7.2</td>
<td>14.3</td>
<td>1.65</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Daily feed intake</td>
<td>120</td>
<td>7.4</td>
<td>108</td>
<td>139</td>
<td>7.9</td>
<td>0.002</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

1P values. Diet effect was nested in trial effect.
2Individual values deduced from 20 other birds from each trial according to the following regression lines: TP21 = 0.247 BW – 55.0 (R² = 0.70); TP21 = 0.136 BW + 24.3 (R² = 0.55); TP21 = 0.138 BW + 21.9 (R² = 0.58); for trials 1, 2 and 3, respectively.
3Individual values deduced from 20 other birds from each trial according to the following regression lines: TL21 = 0.143 BW – 18.0 (R² = 0.14); TL21 = 0.175 BW – 39.7 (R² = 0.18); TL21 = 0.068 BW + 24.5 (R² = 0.12); for trials 1, 2 and 3, respectively.
4Dry matter basis.
lips, respectively. For carbohydrate fractions, the differences between NE/AME and NE/AMEn ratios were slightly more pronounced than for lipids. The mean NE/ME ratios were 0.793, 0.621, 0.682 and 0.590 for starch, total sugars, sucrose + glucose and fermentable sugars, respectively. For non-cell-wall carbohydrates, the mean NE/ME ratio was 0.788 (Table 4).

**Discussion**

In the current experiment, the proportion of energy deposited as lipids varied in a wide range between diets (44.5% to 69.1%). Moreover, no significant relationship ($R^2 = 0.004$; $P = 0.96$; $n = 240$ individuals) was observed between lipid and protein deposition. Thus, the regressions found for predicting NE values (Tables 3 and 4) corresponded to a wide range of metabolic situations.

As previously reported by Hill and Anderson (1958), in vivo NE determinations showed evidences of rather low precision, as shown by the rather high r.s.d. value found for NE values (0.444 MJ/kg DM; Table 1). Trial effects on NE were found whatever the regression calculations (Tables 3 and 4) and showed with very similar patterns in each regression. As rearing conditions were very similar in each trial, these trial effects on NE probably came from difference in chicken metabolism between trials. For instance, difference in bird activity between trials could produce difference in heat production and, hence, difference in NE values between trials.

The mean diet NE/AME ratios (Table 1) were in the range of values previously reported by Farrell (1974) (0.56 to 0.87). The general mean NE/AME ratio (0.764; Table 1) was slightly lower than the mean NE/AME ratio (0.814) found by Geraert *et al.* (1990) in growing chicks from two different genetic lines fed with various diets and higher than the mean NE/AME ratio (0.705) more recently reported by Yang *et al.* (2008).

Investigations in the predictions of NE based on AME or AMEn values failed in finding additional feed characteristics that would improve clearly the NE prediction (Table 2). This has to be associated probably with the rather low variations observed in NE/AME and NE/AMEn ratio between diets (CV of 0.023 and 0.024 between diets, respectively; Table 1).

The current experiment was characterised by the use of pelleted diets with constant amino acid composition of their proteins (except diet 26; Carré *et al.*, 2013) and *ad libitum* feeding. It is possible that other conditions would have changed the results. However, the diet 26 formulated with a high amino acid concentration in their proteins (Carré *et al.*, 1990) and ad libitum feeding. It is possible that other conditions would have changed the results. However, the diet 26 formulated with a high amino acid concentration in their proteins (Carré *et al.*, 1990) showed NE/AME and NE/AMEn ratios (0.744 and 0.775) that did not significantly differ from the ratios obtained with the diet 6 (0.769 and 0.796) formulated with a low amino acid concentration in proteins, as a counterpart of diet 26 (Carré *et al.*, 2013).
Table 4  Regression calculations without intercept \(^1\) (\(n = 30\)) predicting mean in vivo AME\(^2\), AMEn\(^2\) and NE\(^2\) values of diets (MJ/kg) in 4w broilers, using mean digestible nutrient contents\(^3\), and calculations of efficiencies of ME for NE

<table>
<thead>
<tr>
<th>Equation number</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>Efficiencies(^4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DiCP(^5) (g/g)</td>
<td>21.54</td>
<td>19.34</td>
<td>14.47</td>
<td>20.60</td>
<td>18.36</td>
<td>14.32</td>
<td>21.18</td>
<td>18.95</td>
<td>14.23</td>
<td>0.680, 0.760</td>
</tr>
<tr>
<td>DiL(^6) (g/g)</td>
<td>38.60</td>
<td>38.00</td>
<td>32.77</td>
<td>38.38</td>
<td>37.77</td>
<td>32.43</td>
<td>38.56</td>
<td>37.96</td>
<td>32.87</td>
<td>0.849, 0.862</td>
</tr>
<tr>
<td>DiNCC(^7) (g/g)</td>
<td>16.04</td>
<td>15.66</td>
<td>12.50</td>
<td>16.57</td>
<td>16.22</td>
<td>13.07</td>
<td>0.779, 0.798</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DiStp(^8) (g/g)</td>
<td>17.00</td>
<td>16.67</td>
<td>13.28</td>
<td>0.778</td>
<td>0.797</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DiSte(^9) (g/g)</td>
<td>13.02</td>
<td>12.52</td>
<td>7.93</td>
<td>0.781</td>
<td>0.797</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>DiSug(^10) (g/g)</td>
<td>13.02</td>
<td>12.52</td>
<td>7.93</td>
<td>14.94</td>
<td>14.60</td>
<td>10.06</td>
<td>0.674</td>
<td>0.690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suc + Glc(^11) (g/g)</td>
<td>13.17</td>
<td>12.63</td>
<td>7.61</td>
<td>0.609</td>
<td>0.633</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undet(^13) (g/g)</td>
<td>9.93</td>
<td>9.30</td>
<td>12.71</td>
<td>14.94</td>
<td>14.60</td>
<td>10.06</td>
<td>0.674</td>
<td>0.690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean NE/AME</td>
<td>0.978</td>
<td>0.976</td>
<td>0.928</td>
<td>0.984</td>
<td>0.982</td>
<td>0.932</td>
<td>0.981</td>
<td>0.980</td>
<td>0.928</td>
<td></td>
</tr>
<tr>
<td>Mean NE/AMEn</td>
<td>0.156</td>
<td>0.158</td>
<td>0.229</td>
<td>0.135</td>
<td>0.135</td>
<td>0.222</td>
<td>0.146</td>
<td>0.145</td>
<td>0.229</td>
<td></td>
</tr>
</tbody>
</table>

All dietary energy values and contents are expressed on dry matter basis.

\(^1\) NE values were corrected for the trial effects previously determined in the regression models having the trial effect added in models: \(-0.07, +0.23, -0.15\) (equation scheme number 8); \(-0.07, +0.23, -0.16\) (equation scheme number 11); 0.06, +0.22, -0.15 (equation scheme number 14); for trial 1, 2 and 3, respectively. AME and AMEn values were not affected by trial effect. Coefficients were all highly significant \((P = 0.0001)\), except for the coefficients of sugar components \((0.004 < P < 0.086)\) and 'undetermined' \((0.0001 < P < 0.022)\). Models were all significant \((P = 0.0001)\).

\(^2\) AME = apparent metabolisable energy; AMEn = AME corrected to zero nitrogen retention; NE = net energy. AMEn values \((\text{Carré et al. 2013})\) were measured in the same time as NE values, but not with the same individual birds.

\(^3\) Data were those shown in the study published by Carré et al. \((2013)\). For starch P, total reducing sugars and non cell-wall carbohydrates, the digestibility values used for calculation of digestible nutrient contents were obtained by using starch E and fermentable sugars digestibilities, and by considering sucrose and glucose 100% digested components.

\(^4\) Efficiencies assigned to nutrients were calculated as ratios of their NE coefficient to their ME coefficient.

\(^5\) Apparent digestible CP.

\(^6\) Digestible lipids B (acidic treatment before extraction).

\(^7\) Digestible non cell-wall carbohydrates. Non cell-wall carbohydrates = 1 – \(N \times 6.25\) – Lip.B – WICW – Ash; WICW = water-insoluble cell-wall.

\(^8\) Digestible starch P (Polarimetric method).

\(^9\) Digestible starch E (DMSO-enzyme method).

\(^10\) Digestible total sugars (reducing sugar method).

\(^11\) Sucrose + glucose.

\(^12\) Digestible fermentable sugars (lactose and \(\alpha\)-galacto-oligosaccharides).

The *ad libitum* feeding system used in the current experiment is a common practice in broiler experiments, whereas feed is often distributed as a limited meal in other animal species. It is not excluded that the nutritional physiological processes differ between *ad libitum* and meal feeding systems, because *ad libitum* fed animals may eat up to a limit corresponding to some physiological limitations (for instance, heat production or lipid deposition) or corresponding to a precise body requirement. In case of meal feeding, the nutritional physiology may proceed according to an economical efficiency process, which is rather different.

As the cross-correlations between contents of digestible components were low (Carré *et al.*, 2013), sound values can be expected for the coefficients appearing in multiple linear regressions combining these components (Table 4). The values for NE/AME ratios assigned to proteins, lipids and non cell-wall carbohydrates were found to be 0.680, 0.849 and 0.779, respectively (Table 4). These values were in rather good agreement with previous values (De Groot, 1974) with, however, less variation between them compared with those proposed by De Groot in 1974 (0.60, 0.90 and 0.75, respectively). Among digestible carbohydrates, fermentable sugars showed the lowest efficiency of their ME value, which is in agreement with previous results found in growing pigs that also showed low efficiency for fermentable carbohydrates such as hemicelluloses (Noblet *et al.*, 1994). Thus, total sugars showed a rather low efficiency compared with starch, with a difference (0.17; Table 4) that was somewhat higher than that observed in growing pigs (0.09; Noblet *et al.*, 1994). For soybean meal, a feedstuff rich in α-galacto-oligosaccharides, it can be calculated from Table 4 that the replacement of these fermentable sugars by sucrose with genetic selection (Hagely *et al.*, 2013) would increase the NE/AME ratio of this feedstuff by 0.0045.

The NE/ME ratios appearing for undetermined components were rather high (Table 4). However, their reliability was low as undetermined component contents were low and varied little.

As *in vivo* NE determinations require time-consuming and costly experiments, NE estimation of feedstuffs for practical use is often proposed to be obtained by calculation. The calculation method shown in the current publication was similar to that proposed by De Groot (1974) with, first, the calculation of the NE/AME ratio using the efficiency coefficients of nutrients shown in Table 4 and, then, application of this ratio to the actual AME value of feedstuffs. Table 5 shows examples of calculations of NE/AME ratios based on crude component contents. The first step consisted in calculating AMEn and NE values with direct equations (direct equations are based on available nutrients), the NE direct equations being derived from the AMEn direct equations by correcting their coefficients with the NE/ME ratios assigned to nutrients. Then, the NE/AMEn ratio to be applied for a feedstuff was obtained with the NE/AMEn value from Table 5.

The NE/AME values could also be calculated with a better accuracy on the basis of digestible component contents using predicting equations from Table 4, provided that digestibility values are known.

In conclusion, NE/AME ratios were calculated to be 0.760, 0.862, 0.798 and 0.806 for CP, lipids, non cell-wall carbohydrate.
carbohydrates and starch, respectively. A value of 0.680 was obtained for the NE/AME ratio assigned to proteins. The lowest NE/AMEn ratio (0.602) was observed for fermentable sugars (lactose and α-galacto-oligosaccharides). It was explained how these ratios could be used in practice to calculate NE value of feedstuffs. Regression calculations showed that the NE values assigned to individual birds (n = 240) could also be predicted with diet AMEn values (NE = 0.80 AMEn; R² = 0.770) or with an equation combining AMEn value and CP/AMEn ratio (R² = 0.773). The latter ratio was found to be the only additional parameter that was significant when added in the NE regression scheme based on AMEn.

Acknowledgements
This study was supported by a grant from Fonds SYPRAM (funding coming from companies subscribing to ‘Association pour le Maintien de l’Elevage en Bretagne’ (AMEB), ‘Syndicat National des Industriels de la Nutrition Animale’ (SNIA) and ‘Fédération Nationale des Coopératives de Production et d’Alimentation Animales’ (SYNCOpac)) (Broiler Net Energy project, October 1996 to October 1998). Special thanks to the companies which participated in the chemical analyses of diets: CCPA, Celtic, Sanders and UFAC. Authors are grateful to Joelle Gomez, Solange Guillamaux and Jean-Marc Hallouis (INRA, Nouzilly), and to Jean-François Gobin and his team (INRA, Le Magneraud) for their excellent technical assistance. We would like to thank Dr Jean Simon for his participation in the editing of the manuscript.

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