A Study on the Nutrient and Energy Content of Commercial Dog Feeds

Marie Sallander[1], Åke Hedhammar[2], Margareta Rundgren[1] and Jan Erik Lindberg[1]

[1]Department of Animal Nutrition and Management and [2]Department of Small Animal Clinical Sciences, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Abstract

The nutrient and energy content of 45 dry and 5 moist commercial dog feeds most commonly consumed according to a Swedish survey (Sallander et al., 2001) were analysed. The proximate analysis of the dry feeds were shown to be well correlated to the declared values for protein, fat and nitrogen-free extracts (r 0.92-0.94). Although a high correlation, there was a large variation in fat content for single products, and 5 dry feeds showed analysed fat levels at least 20% lower than declared. Over half (53%) of the dry products showed analysed calcium levels at least 20% above or below declared values (range 43-237% of the declared value). For phosphorus, 31% of the dry feeds had analysed levels at least 20% above or below what was declared (range 62-174%).

Feeds of a higher price ($\geq$1.50 SEK/MJ) showed a disagreement between declared values and analysed content for all nutrients analysed of the same magnitude as did feeds of a lower price (<1.50 SEK/MJ).

On average, the content of metabolisable energy using the modified Atwater factors ($ME_{Atwater}$) calculated from the analysed values of protein, fat and nitrogen-free extracts of the dry feeds were in agreement with the $ME_{Atwater}$ based on the declared values. The relationship between the $ME_{Atwater}$ and the ME_{NDF} (metabolisable energy from the analysed NDF-values) for 45 dry feeds were ME_{NDF} = 446 + 0,663 $ME_{Atwater}$ (r 42.6%, P<0.0001). However, when the NDF-values were 14% or higher on a DM-basis, the Atwater factors seemed to over-estimate the energy content by 10-21% in dry feeds, and by 16-37% in moist feeds.

If allowing a deviation of 10% from the AAFCO (2000) nutrient profiles, all dry feeds met the requirements for adult dogs for fat, and only one product had a too low protein level (energy-basis). The phosphorus, magnesium, sodium, iron and manganese levels were sufficient for adult dogs in all dry feeds, but although allowing a deviation of 10%, the levels of some other minerals was too low compared to the AAFCO (2000) norm; calcium (n=1), potassium (n=20), copper (n=2) and zinc (n=4).

It is concluded, that for future studies in canine nutritional epidemiology access to the analysed content of specific nutrients might be necessary as the deviation from the declared values does occur in many dogs feeds regardless if purchased at a high or a low cost.

Introduction

It is well known that diet has an important role in many aspects of health and wellbeing of the dog. A challenge is to formulate feeds that at the same time meet the requirements for both energy and specific nutrients for dogs of varying age, weight, breed and life-stage.

In a previously published survey on Swedish dogs, 98% were fed some type of commercial feed and on average 75% of the energy originated from these products (Sallander *et al.,* 2001a, b). Few reports have been published about the nutrient and energy content of commercial dog feeds (Kronfeld, 1975). The purpose of this study was to evaluate the agreement between the declared and the analysed nutrient content and to estimate the energy content of the commercial feeds examined. The study will give baseline data of the nutrient content of commercial products commonly fed to dogs, but it will also serve as a validation of the declared values of commercial products. The results will be of importance for future epidemiological studies on the effect of diet and physical activity on specific diseases in dogs.

Materials and methods

Feed samples

Samples of 50 commercial feeds representing the most commonly fed products in a previously published survey (Sallander *et al*., 2001a; Table 1) were collected. The majority (79%) of the dogs in the survey were given at least one of the analysed feeds. Forty-five of the products were dry feeds and five were moist representing 22 and 4 brands, respectively. The feeds were bought in packages as small as possible in stores in the city of Uppsala, Sweden. In declared values, 69% of all feeds had protein levels equal to or higher than 22%, and 67% had a fat content of more than 10% on a DM-basis.

Dry feeds

The dry feeds examined were declared as either “low energy/light”-products (13%), “normal” products (60%) or “high energy”-products (27%). Twenty-seven (62%) of the dry feeds selected were imported. The declared values were 18-36% for protein, 5-26% for fat, and 31-64% for the NFE on a DM-basis. The declared values of crude fibre varied between 1.6 and 3.8%, and the ash content between 3.3 and 10.2% (DM-basis). For calcium and phosphorous, the declared values were 0.59-1.82% and 0.53-1.29%, respectively (DM-basis, Table 1). The feeds varied largely in price (0.58-3.13 SEK/MJ), and 51% of the products had a price higher than 1.50 SEK/MJ.

To measure the variability of minerals within feed products, additionally three different batches of the same product were analysed for ten dry feeds.

Moist feeds

Three of the moist feeds were canned, one was a frozen product and one was a semi-moist "sausage". Three out of five products selected originated from Sweden. For moist products, the nutrient levels varied between 34 and 40% for protein, 19-35% for fat, and 11-34% for NFE, 1.5-3.8% for crude fibre, and 7.7-12.5% for ash (DM-basis). For calcium and phosphorus, the declared values were 0.44-2.00% and 0.44-2.50%, respectively (DM-basis, Table 1). The price of moist products were generally higher when compared to dry feeds on an energy-basis (2.1-7.3 SEK/MJ).

Calculations

The content of metabolizable energy ($ME_{Atwater}$) in each commercial product was calculated by using the modified Atwater factors (14.6 kJ/g protein, 35.6 kJ/g fat, 14.6 kJ/g NFE), as adopted in Sweden (Agricultural Board, 1993). In addition, the content of metabolizable energy (ME_{NDF}) derived from the NDF (Neutral Detergent Fibre) content was estimated. The digestibility of energy (dE) was predicted from the equation: dE = 94.8-1.29 x NDF, as suggested by Lindberg & Wandrag (2001). The dietary content of digestible energy (DE_{NDF}) was estimated by multiplying the dE with the calculated gross energy (GE). The GE was estimated after Schieman *et al*. (1971):

GE (MJ/kg DM) = (24.1 CP + 36.6 EE + 20.9 CF + 17.0 NFE) / 1000

(CP crude protein, EE crude fat, CF crude fibre, NFE nitrogen-free extracts in g/kg DM).

The ME_{NDF} was derived by correcting the DE_{NDF} with a urinary energy loss from digestible CP of 5.23 kJ/g as suggested by the AAFCO (2000), and by using an average protein digestibility of 80% as suggested by the NRC (1985).

The data was analysed using Microsoft Excel (Microsoft Software, 1997) and Minitab Statistical Package (Minitab, 2000). The correlations were calculated with the Spearmans rank correlation coefficient. A simple regression equation was estimated between the ME_{NDF} and the $ME_{Atwater}$ using the Minitab Software (1997).

Chemical analysis

Representative feed samples were taken by mixing the content of the feed packages before sampling and milling. The moist feeds were pre-dried in 60°C for 16 hours before analysis. Due to the high fat content, all feeds were ground for 2-3 seconds in a homogenizator (Büchi Mixer B-400), a procedure corresponding to a 1-millimeter sieve. The content of nitrogen was analysed according to Kjeldahl (Nordic Committee on Food Analysis, 1976) using a Kjeltec (Tecator 1030) and crude protein was calculated (N x 6.25). The content of crude fat was analysed according to the Official Journal of European Communities (1984) using a Tecator-equipment (hydrolyse unit 1047 and extraction by Soxtec HT6). The crude fibre was analysed by the short method described by Jennishe & Larsson (1990). The DM and ash determination was made by drying the samples in 103°C for 16 hours, and by ashing in 550°C for 3 hours, respectively. The content of NFE was calculated from the analytical results. Neutral detergent fibre (NDF) was analysed according to Robertson and Van Soest (1977) with a modified procedure (Pettersson & Lindberg, 1997) which included treatment with amylase to delete the starch before the NDF analysis. The fat from each sample was removed with acetone before the NDF-analysis and the crude fibre analysis. Each feed sample was analysed in duplicate.

The mineral analysis was performed by ashing 5.0 g of the milled feeds at 550°C over night, and after cooling to room temperature 10 ml of 7.5M HCl was added. The samples were evaporated and 2 ml 7.5M HCl was added, and the total volume was made up to 50 ml by adding warm distilled water. The samples were diluted 10 times with 0.1M HNO_3, placed in a sand-bath and analysed with optical ICP-AES (Nordic Committee on Food Analysis, 1991).

Results

Dry feeds

Proximate analysis of dry feeds

The analysed DM content of dry dog feeds was on average 92.8% (range 91.9-95.2). The proximate analysis of the dry dog feeds were found to be well correlated with the declared values stated on the packages for protein, fat and NFE (Table 1). The analysed protein content corresponded to on average 103% of the declared values. For fat, the analysed content was on average 104% of that declared. Although a high correlation, there was a large variation in fat content for single products, and 5 dry feeds showed analysed fat levels at least 20% lower than declared.

Also, when comparing the nutrient content on an energy-basis (Table 2), there were high correlations between the declared and analysed values for protein and fat in dry feeds.

Minerals in dry feeds

On both DM and energy-basis, the mineral content of the dry feeds varied largely between products. For example the calcium levels ranged 5.0-fold, while the phosphorus levels ranged 3.2-fold for the analysed feed samples on an energy-basis (Table 2). Other minerals showed the same pattern, and the following had the largest analysed range between products; manganese (7.2-fold), iron (6.9-fold), copper (6.2-fold) and sodium (5.6-fold).

More than half (53%) of the dry products showed analysed calcium levels at least 20% above or below declared values on a DM-basis (range 43-237% of the declared value). For phosphorus, 31% of the dry feeds had analysed levels at least 20% above or below what was declared (range 62-174%).

The analysis of the different batches of the same feeds showed coefficients of variation (CV) between batches ranging from 0.0 to 26.6% for calcium and between 1.2 and 29.5% for phosphorus. Other minerals that showed large CV between batches were sodium (57.8%) and manganese (57.2%) in 2 different feeds (Table 3).

Light, normal and high energy dry feeds

The energy and nutrient contents of dry feeds given attributes describing the energy density (light, normal and high energy) overlapped (Table 4). For crude protein, crude fat and NFE, the correlations between declared and analysed values were generally high. Crude fibre showed a low correlation between the labelled and the proximate analysis for the three types of products (r 0.23-0.33).

The group of "normal" products showed a wider range for fat content (3.6-fold) than light (2.1-fold) and high (2.3-fold) energy products. For protein, all three groups showed range of the same magnitude (1.3-, 1.5- and 1.4-fold for light, normal and high energy products, respectively). In the light products, the analysed calcium levels were on average 28% higher than declared. The correlations between declared and analysed values of calcium and phosphorus were generally low in all 45 dry feeds.

Dry feeds of low and high cost

In the feeds with a price equal to or higher than 1.50 SEK/MJ, the analysed protein levels were on average 109% of the values of cheaper feeds (Table 4). On average, the more expensive feeds showed fat levels corresponding to 135% of the levels in cheaper feeds.

Compared to feeds of a lower price products with a higher price ($\geq$1.50 SEK/MJ) showed a disagreement between declared values and analysed content for all nutrients analysed of the same magnitude. Feeds with price higher or equal to 1.50 SEK/MJ showed analysed levels of protein (% DM) ranging from 91 to 119% compared to the declared levels, while cheaper feeds had a range in protein content between 89 and 127% of declared values. The group of more expensive feeds showed analysed levels of fat that ranged between 75 and 110% of that declared, and the corresponding figures for the feeds below 1,50 SEK/MJ were 69 and 114%. In the group of expensive feeds, the analysed calcium level ranged from 43 to 237% of that declared, and that for phosphorus from 62 to 151%. For the group of feeds of a lower cost, the analysed calcium levels were 69-220% of that declared, while that of phosphorus levels were 63-151% of that declared.

Energy content of dry feeds

On average, the content of metabolizable energy using the modified Atwater factors ($ME_{Atwater}$) calculated from the analysed values of protein, fat and nitrogen-free extracts of the dry feeds were in agreement with the $ME_{Atwater}$ based on the declared values (Table 1).

For light, normal and high energy products there was a large and overlapping range for $ME_{Atwater}$ (Table 4). The average content of $ME_{Atwater}$ were increasing from light to high energy products. The range in $ME_{Atwater}$ between products was comparable for light (1.1-fold), normal (1.2-fold) and high energy (1.2-fold) feeds.

Both for the feeds with a low and high price, the $ME_{Atwater}$ based on analysed values were slightly higher than the $ME_{Atwater}$ based on the declared values (Table 5).

The relationship between the $ME_{Atwater}$ and the ME_{NDF} for 45 dry feeds were ME_{NDF} = 446 + 0,663 $ME_{Atwater}$ (r 42.6%, $P<0.0001$). When the NDF-values were 14% or higher on a DM-basis, the Atwater factors seemed to over-estimate the energy content by 10-21% in dry feeds.

Moist feeds

Proximate analysis of moist feeds

The analysed DM content for moist feeds was on average 21.8% (range 18.2-26.6). The average analysed crude protein levels corresponded to on average 94% of the declared values, and for fat the corresponding figure was 97%. For crude fibre the analysed content was a third of that declared (Table 1). Two moist feeds contained 70 and 80% of that declared for protein, and another two canned products had fat contents corresponding to 67 and 81% of that declared. Consequently, four out of five canned feeds deviated largely from declared values for protein and fat.

Minerals in moist feeds

The calcium levels ranged between 70 and 210% of the declared values, and 3 out of 5 feeds deviated at least 20% from that declared. For phosphorous, 2 out of 5 products deviated more than 20% from the declared values (range 81-202% of the declared values).

The mineral content varied largely between products on an energy-basis, for example the calcium values ranged 5.3-fold, and the phosphorous 3.7-fold (Table 2). Of the other minerals, the content of iron and sodium levels showed the largest variations (9.0- and 7.4-fold, respectively).

Energy content of moist feeds

For moist feeds, $ME_{Atwater}$ calculated from the analysed values were similar to the $ME_{Atwater}$ based on declared values, and the correlation was excellent (0.96, Table 1). The content of ME_{NDF} was on average 22% lower than the $ME_{Atwater}$ values. All moist feeds analysed had NDF-values 14% or higher on a DM-basis, and the Atwater factors seemed to over-estimate the energy content by 16-37%.

Discussion

The present study was performed to examine the energy and nutrient content of commercial dog feeds commonly used in a defined population of dogs. The study shows that there are large variations in nutrient content between commercial dog feeds labelled to be used as complete and balanced for dogs. The range between products for energy-yielding nutrients was high (protein 2.3-fold, fat 7.0-fold, NFE 3.2-fold), while minerals had an even broader range.

Both crude fibre and ash content showed low correlations between declared and analysed values in dry feeds. Also, the analysed calcium and phosphorous levels often showed very large deviations from declared values. Possible reasons for a large deviation in the levels of calcium and phosphorus could be a variation in these minerals in the ingredients used, or that the internal control of the production is limited. It is obvious that many dog feed manufacturers have difficulties to make a product that accurately follows declared values for calcium and phosphorus.

In a similar study of 26 dog feeds approximately 25 years ago, Kronfeld (1975) found that the average values for protein in canned dog feeds (36.7% on a DM-basis) and dry feeds (25.8 and 30.9% on a DM-basis for “dry cereal feed” and “high protein dry feed”, respectively) were similar to the average protein levels of this study. For fat, the values found by Kronfeld (1975) was slightly lower for dry feeds (11.5 and 12.3% on a DM-basis for “dry cerals” and “dry high protein”, respectively) and considerably lower for canned feeds (16.9% DM-basis) than in the present study. For crude fibre, the average levels found in this study corresponded to only 16% of the values reported by Kronfeld (1975) for canned products, and 82% of the figures reported for dry feeds. The large difference in the crude fibre value for canned feeds, might be due to that there was few canned products analysed (5 in each study), and that the fibre content in products rich in animal by-products might be difficult to assess. Animal products often contain sinews or other constituents that when heated could give a crude fibre measurement up to 1% (Hans-Erik Johansson, *personal communication*, Analycen, Lidköping), although there should be no crude fibre in animal tissue. This might be due to that the proteins form Maillard products non-soluble in the crude fibre analysis.

The canned feeds often contain a smaller proportion of vegetabilic products than dry feeds. Therefore, it was surprising that canned feeds showed very high NDF-levels. However, it is possible that soy products, commonly used in canned feeds and rich in pectin, would be a reason for the high NDF-values (Hans-Erik Johansson, *personal communication*, Analycen, Lidköping).

Kronfeld (1975) reported that the calcium levels of commercial feeds were often too high (on average 2.6% in canned feeds and 2.0% in dry feeds on a DM-basis) to be beneficial for optimal health. Moreover, he found 4 products with extremely high calcium levels (2.5-3.2% DM). The average values of calcium in the feeds of our study 25 years later correspond to on average 72 and 67% of that reported by Kronfeld (1975) for dry and canned feeds, respectively. Despite the average lower levels of calcium in todays feed, the deviation from declared values is large and still there are products with levels of calcium that are not compatible with optimal health in dogs if fed as their entire diet. For phosphorous, the present study showed analysed values of dry and canned feeds that corresponded to 78 and 83% of the figures found by Kronfeld (1975). Today, many dry dog feeds seem to be lower in sodium and potassium, and the average levels in the present study corresponded to 62 and 64% of the sodium and potassium in feeds from 1975, respectively. In canned feeds, the levels of sodium and potassium in 1975 and now were corresponding (116 and 99%, respectively).

Nutrient levels in relation to the nutrient requirements

Feeds given to adult dogs

Allowing a deviation of 10% from the AAFCO (2000) nutrient profiles, all dry feeds met the requirements for adult dogs for fat, and only one product had a too low protein level (energy-basis). The protein content of the dry products varied from 85 to 174% of the minimum nutrient profiles for adult dogs, while the fat content met 112-385% of that suggested in the nutrient profiles (AAFCO, 2000).

For dry products, the calcium levels corresponded to between 80 and 399% of the AAFCO profiles for adults dogs, while the phosphorous level reached 93-300%

(energy-basis). The magnesium, sodium, iron and manganese levels were sufficient for adult dogs in all dry feeds, but although allowing a deviation of 10%, still the levels of some other minerals was too low compared to the AAFCO (2000) norm; calcium (n=1), potassium (n=20), copper (n=2) and zinc (n=4). Also, 6 dry feeds showed calcium levels with 2% calcium or more on a DM-basis.

When reanalysing three batches from each of 10 dry feed products, all feeds had a sufficient content of the minerals calcium, phosphorous, magnesium, sodium, manganese and copper for adult dogs. However, 37% of the samples (from 5 feeds) contained too low amounts of potassium compared to the AAFCO nutrient profiles (2000) for adults dogs, and 20% of the samples (originating from 2 feeds) were too low for iron.

All canned feeds met the AAFCO (2000) nutrient profiles for protein, fat, calcium and phosphorous for adult dogs (140-200% of the nutrient profiles for protein, 216-270% for fat, 99-232% for calcium, and 143-332% for phosphorous, respectively). For adult dogs, two canned products contained too low levels of zinc, one contained too low levels of copper, and one feed had too low levels of iron compared to the AAFCO profiles (2000).

Feeds given to growing/reproductive dogs

Out of 45 dry feeds, 32 feeds were declared complete and balanced for all stages of life. If given to growing or reproductive dogs, and if allowing a 10% deviation from the requirements, 3 of the dry feeds had too low levels of protein. Also, one dry feed showed lower analysed levels of fat than recommended on an energy-basis (AAFCO, 2000) for growing or reproducing dogs.

The dry feeds showed calcium levels corresponding to 47-237% of the requirements for growing/reproductive dogs, and three products did meet only 33-57% of the calcium needs. The phosphorous level reached 56-180% of the profiles (energy-basis), and 4 products did meet only 56-85% of the needs. If allowing a 10% deviation from the analysed values, the magnesium, iron and manganese levels were sufficient for growing dogs in all dry feeds. However, some dry feeds did not meet the requirements for growing/reproducing dogs in calcium (n=3), phosphorous (n=4), sodium (n=10), potassium (n=12), copper (n=1), and zinc (n=2).

Only 2 out of 5 moist feeds were declared to be sufficient for growing or reproductive dogs. The first one of these two feeds was sufficient in protein, fat, calcium, potassium, sodium, magnesium, copper, manganese and zinc, but deficient in phosphorous and iron. The other moist feed labelled to be suitable for dogs of all stages of life was sufficient in protein, fat, magnesium, iron and manganese, but deficient in calcium, phosphorus, potassium, sodium, copper and zinc.

Attention should be given to the sometimes high calcium levels as 6 of the dry feeds intended for all stages of life had more than 2% calcium on a DM-basis, and two moist feeds had calcium levels extremely high - 2.64 and 2.75% on a DM-basis. Hedhammar *et al*. (1974) showed that Great Dane puppies fed *ad libitum* a diet containing 2% calcium (DM-basis) developed skeletal abnormalities to a larger extent than those fed the same diet in restricted amounts.

Energy content

Currently, the content of metabolisable energy (ME) in dog feed is estimated from the proximate analysis and the modified Atwater factors (AAFCO, 2000), giving the average energy content in crude protein, crude fat and NFE. This calculation includes an assumed average in vivo digestibility of each class of nutrients. This method to calculate the energy intake has been criticised as it over-estimates feeds rich in fibre, and under-estimates feeds with a high content of fat (Kienzle *et al*., 1998). Possibly, alternative suggested procedures to estimate the dietary energy content in dog feeds (Lindberg & Wandrag, 2001) could improve the precision in the estimates obtained.

In the present study, many dry feeds deviated considerably from the equation describing the relationship between ME_{NDF} and $ME_{Atwater}$ (Figure 1). When the NDF-values were 14% or higher on a DM-basis (which was the case in 27% of the dry feeds, and in all canned feeds) the Atwater factors seemed to over-estimate the energy content by 10-21% in dry feeds, and by 16-37% in moist feeds. On the other hand, with NDF-values below 9% $ME_{Atwater}$ corresponded to 95-98% of the ME_{NDF}. At given energy levels of $ME_{Atwater}$, the range between products for ME_{NDF} was large. This could be due to an inability of the Atwater factors to separate feeds with differences in the content of ME.

Conclusions

An overall impression of the present study is that most feeds that claim to consist of all the nutrients needed do so for the energy-yielding nutrients. However, for the minerals, many feeds appear to have levels too low or high compared to both the declared values and sometimes also to the recommended nutrient profiles (AAFCO, 2000).

It is concluded, that for future studies in canine nutritional epidemiology access to the analysed content of specific nutrients might be necessary as a deviation from the declared values does occur in many dogs feeds regardless if purchased at a high or a low cost.

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Table 1. Nutrient content on a DM-basis of 50 commercial dog feeds commonly used in Sweden

Type of feed	Declared value			Chemical analysis			r_{sp}
Nutrient	Mean	SD	Range	Mean	SD	Range	
Dry feeds (n= 45)							
Crude protein (%)	25.5	4.4	18.3-35.6	26.3	4.6	17.5-37.4	0.92
Crude fat (%)	13.3	5.0	5.4-26.1	12.8	4.9	5.7-24.7	0.94
NFE (%)	48.1	9.0	31.2-63.6	55.2	10.0	34.7-70.4	0.94
Crude fibre (%)	2.8	0.5	1.6-3.8	2.9	0.7	2.0-5.4	0.43
NDF (%)	-	-	-	12.7	2.6	6.7-19.4	-
Ash (%)	7.2	1.3	3.3-10.2	6.9	1.3	3.7-10.4	0.59
Ca (%) [1]	1.38	0.29	0.59-1.82	1.45	0.40	0.51-2.48	0.19, P>0.05
P (%) [1]	1.02	0.18	0.53-1.29	1.01	0.21	0.49-1.50	0.11, P>0.05
Ca/P[1]	1.36	0.23	1.05-2.33	1.43	0.23	1.04-1.92	0.22, P>0.05
$ME_{Atwater}$ (kJ/100 g)	1546	116	1315-1865	1645	93	1499-1890	0.81
ME_{NDF} (kJ/100 g)	-	-	-	1537	95	1380-1794	-
Moist feeds (n=5)							
Crude protein (%)	38.4	2.3	34.4-40.0	36.0	4.2	31.6-40.9	0.67
Crude fat (%)	27.8	5.9	18.7-35.0	26.9	7.7	19.7-39.7	0.98
NFE (%)	20.6	8.7	11.0-34.4	25.6	2.4	22.1-27.9	0.88
Crude fibre (%)	2.3	1.0	1.5-3.6	0.8	0.6	0.4-1.6	0.96
NDF (%)	-	-	-	17.3	3.2	13.8-22.1	-
Ash (%)	10.8	1.7	8.9-12.5	10.8	4.0	5.1-13.9	0.86
Ca (%)	1.37	0.57	0.44-2.00	1.74	0.91	0.66-2.75	0.48, P>0.05
P (%)	1.25	0.76	0.44-2.50	1.34	0.56	0.67-2.01	0.81
Ca/P	1.17	0.27	0.80-1.50	1.31	0.47	0.68-1.86	0.79
$ME_{Atwater}$ (kJ/100 g)	1854	116	1671-1991	1856	210	1664-2203	0.96
ME_{NDF} (kJ/100 g)	-	-	-	1515	117	1343-1604	-

[1]These values are based on 42 feeds, as 3 of the dry feeds were not labelled with the calcium or phosphorous levels.

Table 2. Nutrient content on an energy-basis of 50 commercial dog feeds commonly used in Sweden

Type of feed	Declared value			Chemical analysis			r_{sp}
Nutrient	Mean	SD	Range	Mean	SD	Range	
Dry feeds (n= 45)							
Crude protein (g/MJ)[1]	16.4	2.2	11.7-21.2	16.0	2.6	10.5-21.44	0.90
Crude fat (g/MJ) [1]	8.4	2.5	4.0-14.0	7.6	2.5	3.8-13.1	0.96
Ca (g/MJ) [1]	0.89	0.18	0.38-1.17	0.94	0.26	0.33-1.64	0.13
P (g/MJ) [1]	0.66	0.13	0.34-0.93	0.62	0.13	0.31-0.99	0.34
Ca/P	1.35	0.22	1.05-2.33	1.53	0.24	1.08-2.03	0.15
Mg (g/MJ)	-	-	-	0.13	0.03	0.08-0.23	-
Na (g/MJ)	-	-	-	0.37	0.13	0.11-0.62	-
K (g/MJ)	-	-	-	0.64	0.17	0.35-0.98	-
Fe (mg/MJ)	-	-	-	226	121	98-675	-
Mn (mg/MJ)	-	-	-	46	24	17-123	-
Cu (mg/MJ)	-	-	-	17	8	6-37	-
Zn (mg/MJ)	-	-	-	181	46	100-284	-
Moist feeds (n=5)							
Crude protein (g/MJ) [1]	20.7	0.4	20.1-21.2	19.7	3.9	14.5-24.6	0.24[2]
Crude fat (g/MJ) [1]	14.9	2.3	11.2-17.6	14.3	2.4	11.9-18.0	0.99
Ca (g/MJ) [1]	0.73	0.30	0.26-1.09	0.98	0.58	0.30-1.60	0.41
P (g/MJ) [1]	0.67	0.41	0.26-1.36	0.75	0.35	0.30-1.10	0.71
Ca/P	1.17	0.27	0.80-1.50	1.31	0.47	0.68-1.86	0.79
Mg (g/MJ)	-	-	-	0.06	0.02	0.05-0.08	-
Na (g/MJ)	-	-	-	0.58	0.31	0.11-0.82	-
K (g/MJ)	-	-	-	0.62	0.20	0.35-0.82	-
Fe (mg/MJ)	-	-	-	14.5	15.6	4.7-42.1	-
Mn (mg/MJ)	-	-	-	1.72	0.83	0.75-2.90	-
Cu (mg/MJ)	-	-	-	0.58	0.22	0.39-0.92	-
Zn (mg/MJ)	-	-	-	6.73	3.38	3.57-11.18	-

[1]The energy has been calculated by using the modified $ME_{Atwater}$ factors.

[2]Low value due to one feed product. If that feed was excluded, the correlation would have been 0.65.

Table 3. The variation in analysed mineral content of 3 batches of 10 dry dog feeds

Mineral		Feed number, mean and coefficient of variation (CV)									
		1	2	3	4	5	6	7	8	9	10
Ca	Mean 3 batches (% DM)	1.40	1.00	0.67	1.55	1.73	1.21	1.13	1.24	1.62	2.18
	CV (%)	7.1	0.0	6.0	22.6	13.3	5.8	5.3	26.6	8.0	2.3
	Analysed mean/declared value (%)	86	83	93	160	151	93	79	88	106	120
	Analysed mean/min nutrient profiles adults[1] (%)	233	167	112	258	289	202	189	206	269	363
P	Mean 3 batches (% DM)	0.97	0.85	0.71	1.03	1.24	0.86	0.83	0.95	0.95	1.36
	CV (%)	5.2	1.2	4.2	13.6	8.9	8.1	4.8	29.5	15.8	11.0
	Analysed mean/declared value (%)	105	86	103	137	140	88	84	88	97	106
	Analysed mean/min nutrient profiles adults[1] (%)	162	142	119	171	206	143	139	159	159	226
Mg	Mean 3 batches (% DM)	0.10	0.14	0.09	0.12	0.09	0.13	0.12	0.16	0.17	0.11
	CV (%)	14.6	4.4	1.1	7.5	6.5	9.8	14.2	18.0	9.8	5.3
	Analysed mean/min nutrient profiles adults[1] (%)	258	342	221	300	230	329	300	402	432	286
Na	Mean 3 batches (% DM)	0.36	0.40	0.34	0.29	0.33	0.26	0.39	0.36	0.42	0.37
	CV (%)	30.3	4.2	8.3	9.3	25.9	2.3	23.3	57.8	2.4	14.0
	Analysed mean/min nutrient profiles adults[1] (%)	606	667	564	482	553	439	644	609	698	619
K	Mean 3 batches (% DM)	0.33	0.53	0.55	0.67	0.75	0.49	0.38	0.79	0.84	0.67
	CV (%)	11.6	9.3	20.7	7.0	10.0	11.7	19.7	8.6	11.0	3.1
	Analysed mean/min nutrient profiles adults[1] (%)	54	88	92	112	124	81	63	132	140	111
Fe	Mean 3 batches (mg/kg DM)	140	110	140	149	236	67	61	188	196	328
	CV (%)	32.2	4.0	1.2	23.6	41.4	11.4	5.9	40.6	13.5	20.8
	Analysed mean/min nutrient profiles adults[1] (%)	175	138	175	186	296	84	76	235	244	410
Mn	Mean 3 batches (mg/kg DM)	34.3	33.3	15.1	26.5	91.2	33.8	36.7	35.5	69.1	100
	CV (%)	11.8	1.7	10.6	10.0	11.6	5.6	24.7	57.2	6.8	7.0
	Analysed mean/min nutrient profiles adults[1] (%)	687	667	303	530	1824	676	733	709	1382	2000
Cu	Mean 3 batches (mg/kg DM)	8.3	11.0	11.7	23.9	18.4	10.3	8.6	14.3	22.0	35.7
	CV (%)	34.6	0.0	5.5	13.4	20.7	5.6	3.3	16.3	4.9	19.5
	Analysed mean/min nutrient profiles adults[1] (%)	114	151	160	328	252	141	118	196	302	489
Zn	Mean 3 batches (mg/kg DM)	138.3	72.0	173.4	200.0	249	159.7	127.7	162.0	149.5	240.6
	CV (%)	11.1	3.7	8.3	8.9	7.1	7.1	50.8	68.0	11.4	13.5
	Analysed mean/min nutrient profiles adults[1] (%)	115	60	145	167	208	133	106	135	125	301

[1]AAFCO (2000) dog nutrient profiles

Table 4. A comparison of the nutrient and energy content of dry feeds declared as light/low, adult/normal and high energy on a DM-basis

Type of feed	Declared values			Chemical analysis			Correlation
Nutrient	Mean	SD	Range	Mean	SD	Range	
Light/low energy products (n= 6)							
Crude protein (%)	20.5	1.9	18.3-23.7	20.7	2.3	17.5-23.3	0.72
Crude fat (%)	8.9	2.4	6.5-12.9	8.4	2.6	5.9-12.2	0.78
NFE (%)	58.4	6.0	47.4-63.6	65.9	3.5	60.5-70.4	0.92
Crude fibre (%)	3.4	1.1	2.2-5.4	3.2	0.6	2.4-4.0	0.23
NDF (%)	-	-	-	14.1	3.0	11.5-19.4	-
Ash (%)	6.5	1.6	3.3-7.5	6.2	1.3	3.7-7.1	0.90
Ca (%)	1.16	0.33	0.59-1.54	1.48	0.12	1.29-1.61	0.04
P (%)	0.97	0.28	0.53-1.35	1.06	0.19	0.86-1.39	0.08
$ME_{Atwater}$ (kJ/100 g)	1469	52	1433-1563	1564	60	1511-1668	0.95
ME_{NDF} (kJ/100 g)	-	-	-	1440	63	1380-1524	-
Adult/normal energy feeds (n=27)							
Crude protein (%)	24.3	3.0	18.3-30.2	25.4	3.5	20.2-30.2	0.84
Crude fat (%)	11.7	3.3	5.4-17.2	11.4	3.5	5.7-20.4	0.90
NFE (%)	50.5	5.9	37.7-58.2	58.0	7.1	44.5-69.8	0.86
Crude fibre (%)	2.8	0.6	1.6-3.8	3.0	0.8	2.0-5.4	0.33
NDF (%)	-	-	-	12.2	2.6	6.7-17.4	-
Ash (%)	7.4	1.2	4.5-10.2	7.0	1.3	5.3-10.4	0.50
Ca (%)	1.43	0.23	0.72-1.82	1.45	0.45	0.51-2.48	0.19
P (%)	1.03	0.16	0.67-1.29	1.03	0.24	0.49-1.50	0.42
$ME_{Atwater}$ (kJ/100 g)	1507	82	1315-1660	1622	72	1499-1846	0.51
ME_{NDF} (kJ/100 g)	-	-	-	1536	83	1388-1794	-
High energy feeds (n=12)							
Crude protein (%)	30.6	3.1	25.9-35.6	31.3	3.0	26.6-37.4	0.84
Crude fat (%)	19.0	4.2	12.9-26.1	18.0	4.2	10.8-24.7	0.95
NFE (%)	37.5	5.9	31.2-49.6	43.7	6.9	34.7-55.7	0.90
Crude fibre (%)	2.9	0.8	2.2-4.8	2.7	0.6	2.0-3.9	0.25
NDF (%)	-	-	-	13.3	2.4	10.3-16.4	-
Ash (%)	7.2	1.1	5.3-8.6	7.0	1.1	5.5-8.6	0.56
Ca (%)	1.30	0.19	0.97-1.51	1.44	0.38	0.97-2.13	0.41
P (%)	1.00	0.16	0.74-1.18	0.96	0.14	0.69-1.17	0.34
$ME_{Atwater}$ (kJ/100 g)	1670	113	1467-1865	1736	84	1588-1890	0.90
ME_{NDF} (kJ/100 g)	-	-	-	1588	99	1435-1773	-

Table 5. A comparison of the nutrient and energy content of dry feeds with a cost below and above 1.50 SEK/MJ on a DM-basis

Type of feed	Declared values			Chemical analysis			Correlation
Nutrient	Mean	SD	Range	Mean	SD	Range	
Products < 1.50 SEK/MJ[1] (n= 25)							
Crude protein (%)	24.3	3.4	19.4-31.2	25.5	3.6	20.2-31.3	0.85
Crude fat (%)	11.3	3.6	7.5-20.5	11.0	3.7	6.0-20.5	0.94
NFE (%)	51.3	6.6	36.6-60.3	59.0	7.7	41.4-69.8	0.91
Crude fibre (%)	2.7	0.5	1.6-3.8	3.1	0.6	2.0-4.2	0.47
NDF (%)	-	-	-	12.2	2.2	8.4-16.3	-
Ash (%)	7.0	0.8	5.9-8.6	6.6	1.0	5.4-10.4	0.38
Ca (%)	1.4	0.2	1.0-1.6	1.5	0.4	1.0-2.5	0.21
P (%)	1.0	0.13	0.7-1.2	1.0	0.2	0.7-1.5	0.13
Ca/P	1.4	0.2	1.1-2.3	1.5	0.2	1.1-1.9	0.26
Mg (%)	-	-	-	0.13	0.03	0.09-0.21	-
Na (%)	-	-	-	0.38	0.13	0.16-0.56	-
K (%)	-	-	-	0.62	0.17	0.37-0.90	-
Fe (mg/kg)	-	-	-	228.0	131.2	103.5-675.5	-
Mn (mg/kg)	-	-	-	44.4	15.5	25.8-76.1	-
Cu (mg/kg)	-	-	-	16.9	6.6	7.2-31.2	-
Zn (mg/kg)	-	-	-	173.1	41.4	100.5-272.7	-
$ME_{Atwater}$ (kJ/100 g)	1506	87	1315-1723	1621	71	1510-1805	0.88
ME_{NDF} (kJ/100 g)	-	-	-	1512	67	1388-1630	-
Products ≥1.50 SEK/MJ[1] (n= 20)							
Crude protein (%)	26.9	5.2	18.3-35.6	27.8	5.4	17.5-37.4	0.95
Crude fat (%)	15.7	5.4	5.4-26.1	14.9	5.4	5.7-24.7	0.95
NFE (%)	44.1	10.2	31.2-63.6	50.5	10.7	34.7-70.4	0.94
Crude fibre (%)	2.9	0.5	2.2-3.8	2.8	0.9	2.0-5.4	0.52
NDF (%)	-	-	-	12.3	3.0	6.7-19.4	-
Ash (%)	7.5	1.6	3.3-10.2	7.4	1.5	3.7-10.1	0.66
Ca (%)	1.4	0.4	0.6-2.4	1.3	0.4	0.5-2.3	0.24
P (%)	1.0	0.2	0.5-1.3	1.0	0.2	0.5-1.9	0.10
Ca/P	1.3	0.2	1.0-1.9	1.4	0.2	1.0-1.8	0.32
Mg (%)	-	-	-	0.13	0.03	0.08-0.23	-
Na (%)	-	-	-	0.36	0.13	0.11-0.62	-
K (%)	-	-	-	0.67	0.19	0.35-0.98	-
Fe (mg/kg)	-	-	-	223.5	109.8	98.1-456.9	-
Mn (mg/kg)	-	-	-	48.2	32.1	17.1-123.3	-
Cu (mg/kg)	-	-	-	17.6	8.9	5.8-37.2	-
Zn (mg/kg)	-	-	-	191.6	51.4	100.2-284.2	-
$ME_{Atwater}$ (kJ/100 g)	1595	130	1340-1865	1674	110	1499-1890	0.63
ME_{NDF} (kJ/100 g)	-	-	-	1567	115	1380-1794	-

[1]Energy calculated with the modified Atwater factors.

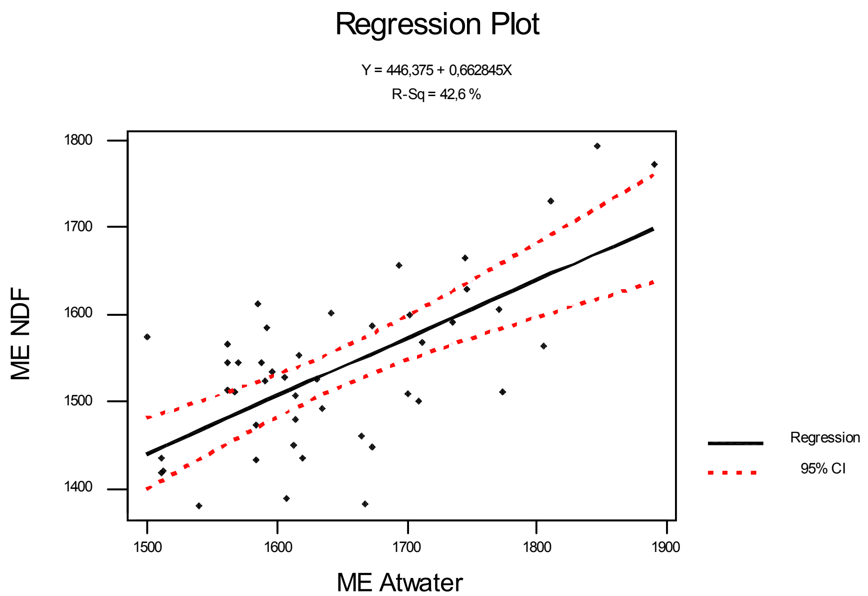

Figure 1. Relationship between the $ME_{Atwater}$ and the ME_{NDF} for 45 dry feeds (ME_{NDF} = 446 + 0,663 $ME_{Atwater}$; r^2=42.6%, P<0.0001.