Calculation of Gross Energy in Pet Foods: Do We Have the Right Values for Heat of Combustion?¹,²

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EXPANDED ABSTRACT

KEY WORDS: • symposium • dietary fiber • prepared pet food • heat of combustion • gross energy

In a previous study considerable discrepancies were observed between measured and calculated heat of combustion or gross energy (GE) of pet foods in data from several laboratories (1). Heat of combustion for all nutrients is covered by a range. Picking one value from that range for calculation of gross energy may result in errors. This might be the case for fiber-containing materials in pet foods such as gelling agents, whose nature and form differ somewhat from those typically present in feeds formulated for agricultural animals. There is limited information on the heat of combustion of these materials. The present investigation was carried out to clarify whether such potential sources of error in the calculation of gross energy are quantitatively relevant in pet foods.

MATERIALS AND METHODS

Food ingredients supposed to provide relatively purified sources of nutrient groups were investigated. Pectin samples were from apple, beet or citrus (34–72% esterified), and there was one sample of pectin conjugated with amino groups and another of pectic acid (6.4% esterified). Three samples of carob bean flour and five samples of caragenan (different degrees of purification), four alginates (high and low viscosity) and one sample of agar agar were analyzed. The gum samples included two guar gums, one tara gum, one gum tragant and one gum arabicum. In addition, two samples of xanthan and inulin and a galactooligosaccharide were analyzed. Twenty-two cellulose samples were investigated, differing in origin (wheat fiber, pine, aspen, eucalyptus, beech, bamboo, cotton wood, hard wood) and treatment (sulfate and sulfite procedure, unrefined, refined, finely graded, microcrystalline). The six lignin samples included one untreated lignin, two lignin sulfonates, one hydrolyzed sample, one that was broken down by NaOH and one that was broken down by Organosolv. Four starch samples (corn starch raw and cooked, potato starch raw and cooked) were analyzed. The protein samples included casein, egg-albumin, lactalbumin, three animal proteins (each derived from tendons), two gluten samples and soy protein. Nonprotein–nitrogen compounds were chitin, D-glucosamine and D-acetylglucosamine. The following fat sources were tested: evening primrose oil, fish oil, beef tallow, refined beef tallow, sunflower oil and refined palm oil. Crude protein (Kjehldal method, N × 6.25), crude fat (acid ether extract), crude fiber and crude ash were analyzed by the Weende method (2). Heat of combustion was determined in an adiabatic bomb calorimeter. Each measurement was repeated five times. If the coefficient of variation within these repetitions exceeded 0.4% the measurements were repeated. Heat of combustion is expressed per unit of organic matter.

RESULTS

All nonstarch-polysaccharides as well as starch and the galactooligosaccharide showed a heat of combustion that was rather close to 4 kcal/g organic matter (Fig. 1). Lignin was the only fiber type that had a different, higher heat of combustion. The heat of combustion of various proteins ranged from 5.28 to 5.88 kcal/g organic matter (Fig. 2). Not surprisingly, the heat of combustion of nonprotein–nitrogen compounds was different from that of protein. For fats the range was between 9.08 and 9.46 kcal/g organic matter.

DISCUSSION

Data are in remarkably good agreement with historical publications on heat of combustion (3). Heat of combustion values of starch and nonstarch-polysaccharide were sufficiently close to 4 kcal/g organic matter to make it unlikely that such materials are a major source of error in the calculation of gross energy in pet foods compared to direct analysis of heat of combustion. With the exception of lignin, which is not a major source of fiber in pet foods, the investigated fiber material was not systematically different from other carbohydrates. This is of practical importance in pet food analysis because,
when carbohydrate and fiber share the same factor, calculated gross energy is independent of the method of fiber determination. Gross energy can be calculated without fiber determination just using one factor for Nfe and fiber combined.

Proteins from egg, milk, connective tissue, cereals and soy were also reasonably close to 5.73 kcal/g organic matter, the factor used for protein in previous investigations (1). These sources of protein did not all contain 100% of crude protein (N × 6.25). With the exception of the animal proteins from tendons the proteins contained considerable amounts of Nfe (between 10 and 26% of organic matter). These samples may contain carbohydrate; for instance, lactalbumin may contain some lactose. It is also possible, however, that the Nfe is only calculated because of a variation of the N-content in the protein. In that case, the crude protein content calculated with factor 6.25 under- or overestimates the protein content of the product. Therefore gross energy was calculated from crude protein, Nfe and fat in organic matter (factors 5.73, 4.06 and 9.08 kcal/g organic matter for protein, Nfe and fat, respectively). The difference between calculated gross energy and heat of combustion was <0.5 kcal/g organic matter in all investigated protein sources. This makes it extremely unlikely that proteins are a major source of error in the calculation of gross energy in pet foods. The three nonprotein–nitrogen compounds showed surprisingly little difference between calculated gross energy (from crude nutrients, including crude protein calculated by N × 6.25) and heat of combustion. In the case of chitin calculated gross energy amounted to 5.0 kcal/g organic matter and heat of combustion to 4.9, for D-acetyl-glucosamine the results were 4.3 and 4.7 kcal/kg organic matter, respectively. In the case of D-glucosamine the difference was somewhat larger (3.5 vs. 4.7 kcal/g organic matter). The pectin conjugated with amino groups had a heat of combustion of 3.65 compared to a calculated gross energy from proximates of 4.34 kcal/g organic matter. Therefore, even the inclusion of some nonprotein–nitrogen such as glucosamine into pet foods is unlikely to be a major source of error for the calculation of gross energy.

Heat of combustion of tallow, fish oil, evening primrose and sunflower oil ranged between 9.39 and 9.46 kcal/g. Heat of combustion of palm oil was somewhat lower, amounting to 9.08 kcal/g. In general, the chain length of the fatty acids in palm oil is shorter than that in the other fats tested, which agrees with the general rule that heat of combustion of fatty acids increases with increasing chain length. Assuming typical degrees of desaturation for the fat samples that were analyzed, desaturation (decreasing heat of combustion with increasing desaturation) is quantitatively less important than chain length. The factor of 9.08 kcal/kg organic matter used in our former investigations (1) appears to be at the lower range of the investigated samples and, especially for the type of fat that is expected in pet foods, this factor appears to be somewhat too low. However, the difference is still not large enough to explain discrepancies of up to 20% between gross energy and heat of combustion.

LITERATURE CITED

