

ARTICLE

Interpreting Pet Food Labels: A Mathematical Approach to Nutrient Bases

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Introduction

Nutrition labels present a collection of quantitative summaries, where each percentage represents a ratio of nutrient concentration to a specified reference variable — such as food mass, moisture level or energy density. Because pet food products vary widely in both moisture content and energy density, these reference variables are not interchangeable. Mathematics allows direct comparison of nutrient concentrations between products, even when they appear very different at first glance.

Each basis — as-fed (AF), dry matter (DM) or caloric (C) — uses a unique denominator that fundamentally changes how the same underlying nutrient composition is perceived. The choice of denominator determines the apparent value of a nutrient's concentration. For example, a product that appears lower in protein may only appear that way because its denominator includes water weight or because it reflects a different energy density.

Understanding which denominator is used and how to convert among them is fundamental to interpreting pet food labels (Case et al. 2011). Through basic algebraic conversions and ratio logic, these bases can be transformed to provide meaningful comparisons across product types.

The sections that follow develop a mathematical framework for understanding how the denominator affects apparent nutrient concentration and how algebraic transformations enable accurate comparisons across different types of pet food.

Understanding Nutrient Bases

Each basis represents the same nutritional composition viewed through a different mathematical lens. This distinction lies entirely in the denominator — the reference quantity to which the nutrient amount is compared (Case et al. 2011). Nutrient concentration can be represented generally as:

$$Nutrient\ \ concentration\ \ = \frac{Nutrient\ \ amount}{Reference\ \ variable}$$

The reference variable in the denominator defines whether the nutrient concentration is expressed per total food weight, dry-matter weight or per unit of energy. Changing the denominator alters the apparent value of the nutrient, even though the nutrient's actual quantity in the food remains constant. This denominator effect is a common source of confusion in interpreting pet food labels (FEDIAF 2024).

For example, a canned food with high moisture may list a protein content of only 10% on an as-fed basis, while a dry kibble may list a protein content of 30%. Without adjusting for water weight, the kibble appears to be three times richer in protein, yet its dry-matter protein content may be similar. This is because water contributes mass but no nutrients. When water constitutes a large proportion of total food mass (as in canned products), it increases the denominator in the as-fed calculation while contributing nothing to the numerator. This reduces the apparent nutrient concentration without altering the actual amount of nutrients available in the food's dry portion.

Understanding dimensional consistency—ensuring that units in calculations are compatible—is essential when working with nutrient bases. Each nutrient concentration must maintain dimensional integrity, meaning the units of the numerator must be appropriately scaled to the units of the denominator.

For instance, when expressing protein content, if the numerator is given in grams and the denominator is

given in kilograms, the resulting concentration has units of grams per kilogram (g/kg), which can be converted to a percentage by dividing by 10. To see why, consider that 1 kilogram equals 1,000 grams. If a food contains 10 grams of protein per 1 kilogram (1,000 g) of food, this can be written as 10 grams per 1,000 grams. Dividing both the numerator and denominator by 10 gives 1 gram per 100 grams, which is the definition of 1%. Therefore, 10 g/kg equals 1%.

This concept becomes particularly important when converting between bases. Maintaining consistent units prevents scaling errors that distort nutrient concentrations, ensuring accurate representation of nutrient levels. With this dimensional framework established, the specific mathematical properties of each basis can now be examined.

The As-Fed Basis

The as-fed (AF) basis expresses nutrient amounts relative to the product's total weight, including water and dry matter. The denominator in this basis is the food's total mass. This is the form required by labeling regulations, such as the Association of American Feed Control Officials (AAFCO 2024), which specifies that guaranteed analyses must reflect the food as it is sold and consumed.

The nutrient concentration on an as-fed basis can be mathematically represented as:

$$Nutrient_{AF} = \frac{Nutrient\ \ mass}{Total\ \ food\ \ mass} \times 100$$

In the equation above, multiplying by 100 converts the resulting decimal fraction to a percentage. As-fed nutrient values are also frequently expressed in units of grams per kilogram (g/kg) or milligrams per kilogram (mg/kg). To convert from a percentage to g/kg, multiply by 10:

$$Nutrient_{AF}\ (\text{g/kg}) = Nutrient_{AF}\ (\%) \times 10$$

For example, a protein value of 12% on an as-fed basis equals 120 g/kg.

Because the denominator includes the weight of water, and water contributes to total weight but contains no nutrients, it dilutes the apparent concentration of nutrients when expressed on this basis (NRC 2006). For example, if 100 g of canned food contains 75 g of water and 12 g of protein, then:

$$Protein_{AF} = \frac{12}{100} \times 100 = 12\%$$

This value represents the nutrient as a percentage of the total mass. However, it does not account for the fact that 75% of that mass is water, which provides no nutritional contribution.

Different forms of pet food can vary drastically in moisture content. Dry kibble typically contains approximately 10% moisture, whereas canned or fresh diets can contain 60-80% moisture (U.S. Food and Drug Administration 2020). Because of this discrepancy, nutrient values are not directly comparable on an as-fed basis between products with different moisture content.

For example, a dry kibble with 30% protein on an as-fed basis and 10% moisture appears to have far more protein than a canned food with 12% protein on an as-fed basis and 75% moisture. However, this comparison is misleading because it does not account for the moisture discrepancy between the products, as demonstrated in the dry-matter basis section below.



The Dry-Matter Basis

The dry-matter (DM) basis expresses nutrient quantities relative to the product's dry matter, excluding water entirely. Dry matter is defined as the portion of food remaining after all moisture has been removed. Algebraically, this means changing the denominator from total mass to dry-matter mass only. Because nutrients are present only in food's dry matter, this basis provides a more consistent measure of nutrient density across products with varying water content (Case et al. 2011).

To convert nutrient values from as-fed to dry matter, the following equation is used:

$$Nutrient_{DM} = \frac{Nutrient_{AF}}{100 - Moisture_{AF}} \times 100$$

This equation requires that both nutrient and moisture values are expressed as percentages on an as-fed basis. The term (100 - $Moisture_{AF}$) represents the percentage of dry matter in the product.

Here, the denominator is dry-matter mass — the fraction of the food that contains nutrients. Dry-matter mass is a fraction of the entire product, meaning it is a smaller value than the total food mass. This change in the denominator alters the apparent nutrient density, not by changing the nutrient content, but by changing the definition of "100%."

Dividing by the smaller dry-matter mass rather than the larger total mass (as in the as-fed basis) results in a higher percentage. This increase reflects the actual concentration of nutrients in the portion of the food that contains them. This approach eliminates moisture as a confounding variable (Case et al. 2011).

To understand why this conversion works, it is helpful to consider the dimensional analysis:

$$\frac{Nutrient_{AF} \ (\%)}{100 - Moisture_{AF}} \times 100$$

Which expands to:

$$\frac{grams \ of \ nutruent \ per \ 100 \ grams \ of \ food}{grams \ of \ dry \ matter \ per \ 100 \ grams \ of \ food} \times 100$$

The "per 100 grams of food" terms cancel out, resulting in:

$$\frac{grams \ of \ nutrient}{grams \ of \ dry \ matter} \times 100 = \% \ \text{DM}$$

This yields nutrient concentration expressed as grams per 100 grams of dry matter, which is the definition of dry-matter percentage.

Returning to the previous example, suppose a canned food contains 75% moisture with 12% protein, and a dry kibble contains 10% moisture with 30% protein.

To calculate the dry-matter protein percentages of the canned food and dry kibble, the dry-matter conversion equation can be applied:

$$Protein_{DM,canned} = \frac{12}{100 - 75} \times 100 = 48\%$$

$$Protein_{DM,dry} = \frac{30}{100 - 10} \times 100 = 33.33\%$$

Although the canned food appears to have a lower protein percentage on the label (12% vs. 30%), on a dry-matter basis, it actually contains 48% protein, compared to 33% in the kibble.

Converting from Dry-Matter to As-Fed Basis

While the primary need is often to convert from as-fed to dry-matter, the reverse conversion is equally important.

Dry matter values can be converted to an as-fed basis by rearranging the previous equation:

$$Nutrient_{AF} = Nutrient_{DM} \times \frac{100 - Moisture_{AF}}{100}$$

The term $\frac{100 - Moisture_{AF}}{100}$ represents the decimal fraction of the product that is dry matter. Multiplying the dry-matter nutrient concentration by this fraction reintroduces the moisture dilution, scaling the nutrient percentage back down to reflect its concentration in the total food mass.

Suppose a gently cooked, fresh diet contains 60% protein on a dry-matter basis and 65% moisture. To find the as-fed protein percentage, the above equation can be used:

$$Protein_{AF} = 60 \times \frac{100 - 65}{100} = 21\%$$

This calculation shows that a product with 60% protein on a dry-matter basis would display only 21% protein on its guaranteed analysis panel when the product contains 65% moisture. This significant reduction demonstrates the impact of moisture on as-fed values and underscores the importance of accounting for moisture content when interpreting pet food labels.



The Caloric Basis

While the dry-matter basis allows for a direct comparison of nutrient density by eliminating the effect of moisture, it does not account for energy density — the amount of metabolizable energy contained per unit of food. Energy density can vary substantially among products, meaning even if two products have identical nutrient percentages on a dry-matter basis, the nutrients delivered per calorie consumed can differ significantly. The caloric basis shifts the denominator from mass to energy.

The following equation can be used to convert as-fed nutrient concentrations to a caloric basis:

$$Nutrient_c = \frac{Nutrient_{AF}}{Energy\ \ density} \times 1{,}000$$

It is important to note that the numerator and denominator in the above equation must be expressed in the same unit system. For example, if the numerator represents grams of a nutrient per kilogram of food, and the denominator represents kilocalories per kilogram, both quantities are scaled relative to one kilogram. This maintains dimensional consistency and ensures that the resulting value correctly expresses nutrient density relative to energy intake. However, if protein is expressed as a percentage (g per 100 g) but energy density is given in kcal/kg, the calculation cannot proceed correctly because the quantities refer to different amounts of food. Both must first be converted to per kilogram before continuing to calculate the nutrient concentration.

When both quantities are per kilogram, the kilogram units cancel, leaving:

$$\frac{g\ \ nutrient}{kcal} \quad \times 1{,}000 = \frac{g\ \ nutrient}{1{,}000\ \ kcal}$$

Multiplying by 1,000 scales the result to a more practical reporting unit — grams of nutrient per 1,000 kcal (g/1,000 kcal) rather than per 1 kcal.

Two foods with identical nutrient concentrations on an as-fed or dry-matter basis may deliver different amounts of nutrients when consumed to meet their daily energy needs because animals regulate food intake based on energy requirements rather than food mass (Case et al. 2011). A food with higher energy density satisfies energy needs with less food consumed, while a food with lower energy density requires greater intake to meet the same energy requirement. However, the nutrients delivered per calorie depend on how the food was formulated: a high-energy-density diet can be formulated to provide the same nutrient concentration per calorie as a lower-energy-density diet, or it may differ substantially.

Returning to our previous example: suppose a dry kibble contains 30% protein on a dry-matter basis with 10% moisture and 3,500 kcal/kg, and a canned food contains 48% protein on a dry-matter basis with 75% moisture and 1,500 kcal/kg. To calculate the protein value on a caloric basis:

(1) Convert dry-matter protein to as-fed

$$Protein_{AF,canned} = 48 \times \frac{100 - 75}{100} = 12\%$$

$$Protein_{AF,dry} = 30 \times \frac{100 - 10}{100} = 27\%$$

(2) Convert as-fed protein units from % to g/kg

$$Protein_{AF,canned} = 12 \times \quad 10 = 120\frac{g}{kg}$$

$$Protein_{AF,dry} = 27 \times \quad 10 = 270\frac{g}{kg}$$

(3) Convert to caloric basis

$$Protein_{C,canned} = \frac{120}{1500} \times 1{,}000 = 80\frac{\text{g}}{1{,}000\ \ kcal}$$

$$Protein_{C,dry} = \frac{270}{3500} \times 1{,}000 = 77.14\frac{\text{g}}{1{,}000\ \ kcal}$$

On a dry-matter basis, the canned food appears substantially higher in protein (48% vs. 30%). However, on a caloric basis, the two products deliver similar amounts of protein: 80 g/1,000 kcal for the canned food versus 77.14 g/1,000 kcal for the kibble.

This similarity exists because the canned food, despite having a higher protein concentration per gram of dry matter, has much lower energy density. Animals must consume more of the canned food to meet their energy requirements, which offsets the difference in concentration. The caloric basis shows that both products would deliver approximately the same amount of protein when animals consume enough of each food to meet the same energy requirement.

Applying All Three Bases



Having examined each basis individually, a direct comparison across multiple product types demonstrates how these conversions work together in practice. Consider four different types of pet food with the following specifications:

Product	Moisture (%)	$Protein_{AF}$ (%)	Energy Density (kcal/kg)
Dry Kibble	12	27	3,800
Canned Food	76	10	1,000
Fresh/Cooked	68	15	1,300
Freeze-Dried	5	43	4,200

Using the conversion equations developed throughout this paper, protein content can be calculated across all three bases. The dry-matter conversions follow the equation introduced earlier:

$$\text{Protein}_{\text{DM}} = \frac{\text{Protein}_{\text{AF}}}{100 - \text{Moisture}_{\text{AF}}} \times 100$$

For the caloric basis, the as-fed values are first converted to g/kg, then divided by energy density and multiplied by 1,000:

$$\text{Protein}_{\text{C}} = \frac{\text{Protein}_{\text{AF}}\text{x}10}{\text{Energy density}} \times 1{,}000$$

Applying these conversions:

$$Protein_{DM,kibble} = \frac{27}{100-12} \times 100 = 30.68\%$$

$$Protein_{DM,canned} = \frac{10}{100-76} \times 100 = 41.67\%$$

$$Protein_{DM,fresh} = \frac{15}{100-68} \times 100 = 46.875\%$$

$$Protein_{DM,freeze-dried} = \frac{43}{100-5} \times 100 = 45.26\%$$

$$Protein_{C,kibble} = \frac{27\text{x}10}{3{,}800} \times 1{,}000 = 71.05 \frac{\text{g}}{1{,}000 \quad kcal}$$

$$Protein_{C,fresh} = \frac{15\text{x}10}{1{,}300} \times 1{,}000 = 115.38 \frac{\text{g}}{1{,}000 \quad kcal}$$

$$Protein_{C,canned} = \frac{10\text{x}10}{1{,}000} \times 1{,}000 = 100 \frac{\text{g}}{1{,}000 \quad kcal}$$

$$Protein_{C,freeze-dried} = \frac{43\text{x}10}{4{,}200} \times 1{,}000 = 102.38 \frac{\text{g}}{1{,}000 \quad kcal}$$

These calculations yield the following comparison:

Product	$Protein_{AF}$ (%)	$Protein_{DM}$ (%)	$Protein_{C}$ ($\frac{\text{g}}{1{,}000\text{kcal}}$)
Dry Kibble	27	30.68	71.05
Canned Food	10	41.67	100
Fresh/Cooked	15	46.875	115.38
Freeze-Dried	43	45.26	102.38

These conversions reveal important insights that are hard to see from as-fed values alone. The freeze-dried food appears to contain more than four times the protein of the canned food, when comparing as-fed percentages (43% vs. 10%). However, on a dry-matter basis, these products have relatively similar protein concentrations (45.26% vs. 41.67%). On a caloric basis, they deliver nearly the same amount of protein per 1,000 kcal consumed (102.38 g/1,000 kcal vs. 100 g/1,000 kcal).

Similarly, the fresh food shows the second-lowest protein content on an as-fed basis (15%), yet it delivers the highest protein per calorie (115.38 g/1,000 kcal)—over 60% more than the kibble. This occurs because the fresh food has a relatively low energy density. To meet their daily caloric requirements, animals must consume a greater mass of this food. Since the water in the food contributes no calories, the animal consumes proportionally more of the nutrient-containing dry matter, thereby increasing total protein intake per unit of energy.

The dry-matter basis reveals that three of the four products have similar protein concentrations (41–47%), while the kibble is notably lower (30.68%). Accounting for energy density shows that the kibble delivers the least protein per unit of energy intake, despite having the second highest as-fed percentage.



When to Use Each Basis

Each basis serves a distinct analytical purpose by changing the denominator to reveal different aspects of nutrient composition. The selection of an appropriate nutrient basis depends on the specific comparison being made.

The as-fed basis is best suited for evaluating the product exactly as it will be consumed. Because labeling regulations require guaranteed analyses to reflect the product in its purchased form (AAFCO 2024), the as-fed basis remains the standard format for product labels. This basis is also useful when calculating feeding portions, as instructions must correspond to the product's total weight, including moisture. However, the as-fed basis should not be used to compare nutrient concentrations between products with different moisture contents, as water mass obscures true nutrient density.

The dry-matter basis is best suited for comparing nutrient concentrations across products with varying moisture levels. By excluding water from the denominator, this basis enables direct comparison of nutrient density regardless of product form (Case et al. 2011). This basis is particularly valuable for evaluating whether a food meets minimum nutrient requirements or for identifying differences in nutrient concentration between product forms. However, it does not account for energy requirements and therefore does not reflect nutrient delivery in practice.

The caloric basis evaluates nutrient delivery when food is consumed to meet daily energy needs. Because animals regulate food intake primarily by energy requirements rather than by mass (Case et al. 2011), the caloric basis most accurately reflects nutrient intake in practice. This basis is essential when comparing foods with substantially different energy densities or when assessing whether a product provides adequate nutrients at typical feeding amounts.

In practice, a complete nutritional evaluation often requires examining all three bases sequentially. The as-fed basis reflects regulatory requirements and represents the product as purchased. The dry-matter basis reveals whether apparent differences represent true compositional differences or result from moisture variation. The caloric basis determines whether those differences translate to meaningful nutrient delivery when animals consume food to meet energy requirements. Each basis provides a different mathematical perspective on the same nutritional composition, and selecting the appropriate basis—or combination of bases—depends on the analytical objective.



Conclusion

Each nutrient basis—as-fed (AF), dry matter (DM), and caloric (C)—describes the same nutritional composition using a different reference variable in the denominator. As established throughout this paper, the denominator fundamentally determines how nutrient concentration appears, even though the actual quantity of nutrients remains constant. Understanding the mathematical relationships between these bases is essential for accurately comparing different forms of pet food.

The as-fed basis uses total food mass as its reference variable. This is the format required on pet food labels, guaranteed analysis panels, and product feeding instructions because it reflects the product exactly as it is purchased and consumed (AAFCO 2024). However, because water contributes weight

without providing nutrients, it dilutes the apparent nutrient concentration. The dry-matter basis removes moisture as a confounding variable by changing the denominator from total mass to dry-matter mass alone, revealing the actual nutrient concentration in the food (Case et al. 2011). While this basis allows direct comparison among foods with varying moisture levels, it does not account for differences in energy density. The caloric basis addresses this by changing the denominator from mass to energy density. By expressing nutrients per unit of metabolizable energy rather than per unit of mass, this basis reflects how animals actually use food, not just how it is measured in the bowl.

The algebraic conversions outlined in this paper are simple yet powerful: recognizing that every percentage represents a ratio with a specific denominator and understanding how changing that denominator affects apparent concentration allows for accurate interpretation of pet food composition. Selecting the appropriate basis—or using all three in sequence—depends on the comparison being made. By identifying the denominator, ensuring dimensional consistency, and converting nutrients to a common basis, one can move beyond surface-level percentages to assess the true nutritional value of pet food.

References

AAFCO, 2024, *Official Publication*, Association of American Feed Control Officials, Champaign. Available at: https://www.aafco.org/publications/official-publication.

Case LP, Daristotle L, Hayek MG and Raasch MF, 2011, *Canine and feline nutrition: a resource for companion animal professionals*, 3rd edn., Mosby Elsevier, Maryland Heights.

FEDIAF, 2024, *Nutritional guidelines for complete and complementary pet food for cats and dogs,* European Pet Food Industry Federation, Brussels. Available at: https://fediaf.org/39-nutritional-guidelines.html.

NRC, 2006, *Nutrient requirements of dogs and cats,* National Academies Press, Washington. Available at: https://nap.nationalacademies.org/catalog/10668/nutrient-requirements-of-dogs-and-cats.

U.S. Food and Drug Administration, 2020, *Pet food labels – general,* Center for Veterinary Medicine, Silver Spring. Available at: https://www.fda.gov/animal-veterinary/animal-health-literacy/pet-food-labels-general.



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