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COMMENTARY

Skepticism and Science: Responsibilities of the Comparative Nutritionist

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Comparative nutritionists are asked to formulate diets for over 3,000 species of animals,including mammals, birds, reptiles, amphibians, fish, and invertebrates. Little research has been conducted to provide an information base for this task, and both popular and scientific publications contain factual errors and irrational concepts that confuse the user. When data are suspect and theories do not make sense, they should be viewed skeptically. Untruths should not be perpetuated by uncritical repetition, and unsubstantiated information should be replaced as promptly as possible through controlled scientific study. Progress in this field can best be made through the cooperative efforts of qualified individuals. The ultimate personal reward should be the health and welfare of the animals we propose to feed. © 1996 Wiley-Liss, Inc.

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INTRODUCTION

There are human nutritionists, beef cattle nutritionists, dairy cattle nutritionists, poultry nutritionists, swine nutritionists, dog and cat nutritionists, fish nutritionists, and veterinary nutritionists (for goodness sake), but few of us have been brash enough to label ourselves comparative nutritionists.

Maybe it's an ego thing. It certainly requires lots of self confidence to believe that one is a jack-of-all-trades and master of every issue. For most of us (including myself), the title "Comparative Nutritionist" requires qualification—something like "for aardvarks only," or "when I'm out of town and nobody knows me," or "when my audience knows even less about the subject than I do."

In every profession there are those who speak with great conviction about personal positions when the truth is unknown. United States congresspeople do it every day. But that is not the way of science. Those of you who have been admitted to Sigma Xi, The Scientific Research Society, may remember its motto, "To Search

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for Truth." That is a lofty creed, with a message that should be as immutable as the 10 commandments. Perhaps, for us, it should be the 11th.

THE CHALLENGE

Wilson [1992] has estimated that 1,143,000 species of living organisms are known. About 248,000 are higher plants, and of the remainder, 1,032,000 are animals. Included are 4,000 mammals, 9,000 birds, 6,300 reptiles, 4,200 amphibians, and 18,000 fish and lower chordates. Within the world's zoos, somewhat more than 3,000 species of mammals, birds, reptiles, and amphibians are represented, about 13% of the known species of terrestrial vertebrates. This is not a large number, compared to the total, but development of diets that will nourish those species appropriately is a very daunting task. That task is enlarged significantly when the captive collections of fish and invertebrates are included.

Nutritionists who are responsible for the diets of humans, laboratory animals, farm animals, and dogs and cats have access to specific documents on nutrient requirements of those species from the National Research CounciL'National Academy of Science, Washington, DC. These documents derive their veracity from the published research of hundreds of scientists and the peer review process that endeavors to separate fact from fiction.

Comparative nutritionists responsible for the other 3,000 + species have no such documents. Controlled nutrition research has been conducted with few wild species, and the information base for most is extremely limited. Robbins L1993i has assembled much useful information in *Wildlife Feeding and Nutrition.* However, the formulation of diets for most zoo and aquarium animals still requires extensive extrapolation of data, from species with known nutrient needs, and major applications of faith.

MEETING THE CHALLENGE

This treatise is not intended as a complete guide to formulating diets for captive wild animals, but it is appropriate to list some useful principles.

1. Learn as much as possible about feeding strategy and nutrient composition of chosen and rejected foods in the natural habitat.
2. Explore the morphology and physiology of the gastrointestinal system from lips to anus. Consider functions of specialized structures used in acquisition and processing of food.
3. Use specific nutrient requirement information generated with the species.
4. Apply information generated with species having similar dietary habits and gastrointestinal morphology and physiology.
5. Pray or cross your fingers, whichever is politically correct in your culture.

SKEPTICISM

The literature includes myriad examples of unproven postulates masquerading as facts. In the minds of some, words that are written down assume an unchallengeable legitimacy. Everyday experience with the local newspaper should belie such

TABLE 1. Calcium and corrected phosphorus concentrations (dry matter basis) in squid, clams, and fish [Bernard and Ullrey, 1989]*

Species	Calcium, %	Corrected phosphorus, %
Loligo sp. (squid)	0.11	1.21
Spisula solidissima (clams)	0.17	0.61
Mallatus villosus (capelin)	2.18	1.99
Thaleichthys pacificus (Columbia River smelt)	1.25	1.12
Thaleichthys pacjficus (Columbia River smelt)	0.93	1.03
Clupea harengus (Atlantic herring)	1.70	1.63
Scomberomorus maculatus (Spanish mackerel)	1.20	1.13
Scomberomorus maculatusa (Spanish mackerel)	0.60	1.08
Scomberomous maculatusb (Spanish mackerel)	0.87	1.17
MaIlatus villosus (capelin)	1.19	1.34
Clupea harengus (Atlantic herring)	1.63	1.00
Scomberomorus japonicus (Pacific mackerel)	1.55	1.21

*Data presented in the same order as in Table 2, p. 47.
[a]Head and fins removed.
[b]Postanal section with fins removed.

an assumption, and it is clear that we should be taught not only *how* to read but *to question what* we read.

Previously, it was stated that there is a peer review process to which published research is subject. The intent of peer review is to ensure that the scientific literature is not cluttered with falsehoods while encouraging inclusion of substantiated truths. As an author, reviewer, and former journal editor, I can say that the process does not always work.

There are always explanations (excuses). The reviewers were rushed. The reviewers were not qualified. The editor did not accept the reviewers' recommendations. Whatever the reason, when set in black and white, errors tend to persist forever.

There are exceptions, of course, particularly for big mistakes. Before Galileo, the earth was the center of our universe, and the church fiercely defended that position; but even the papacy could not prevail against such an egregious error. Unless there is a conspiracy among astronomers and NASA, the sun now occupies that central spot, and the scientific literature has been corrected.

Some other errors in the scientific literature have not been corrected, however, and in an act of personal penance, I would like to rectify that now. An associate and I inadvertently included faulty values in a published paper [Bernard and Ullrey, 1989]. The significance of these values is several hundred orders of magnitude below the importance of Galileo's work, but this correction should make us feel better.

Recently, our laboratory completed analyses of several species of fish that are used by zoos and aquariums in the feeding of piscivorous birds and mammals. In comparing the more recent data with values we published previously, it was noted that the concentrations of phosphorus were markedly different. An examination of our laboratory workbooks revealed a miscalculation in the previously reported phosphorus values, and corrections are presented in Table 1. We would like to accompany these corrections with an apology to those who have used the incorrect values and, as a consequence, may have been misled. The original correct concentrations of calcium are included for purposes of comparison.

The stimulus for these corrections was the fact that it did not make sense for phosphorus concentrations in the same species of fish to differ three- to fourfold just because they were sampled at widely different times.

And that is where skepticism comes in. If data or ideas do not make sense - if concepts or explanations or theories are not rational - it is time to take a hard and skeptical look.

SCIENCE

Comparative nutritionists who have been working in the field very long have found lots of things to be skeptical about. Sometimes it seems entire careers are built upon publishing misinformation or promoting irrational practices. As a consequence, much more time than is desirable must be spent in the pursuit of truth among a morass of falsehoods and disingenuous ideas. It must be admitted, however, that some of these pursuits lead in exciting directions and provide excellent opportunities to train graduate students.

One such pursuit was stimulated by assertions that ulcerative stomatitis, or "mouth rot," in captive snakes and lizards was a consequence of vitamin C deficiency. While it is possible that some reptile species may have a dietary ascorbic acid requirement, Chatterjee [1970] reported that the reptiles that had been studied were able to synthesize ascorbic acid in their kidneys. Vosburgh et al. [1982] randomly assigned eight plains garter snakes *(Thamnophis radix)* and 15 eastern garter snakes *(T. sirtalis sirtalis)* to two treatments from weight and species outcome groups. A semipurified diet containing either 0 or 500 mg ascorbic acidlkg dry matter was tube fed to the snakes 2—3 times per week.

Three methods were used to definitively test whether these garter snakes could synthesize ascorbic acid. One method involved placing snakes in air-tight metabolic chambers, administering a radiocarbon-labeled dose of ascorbic acid, and measuring respired $^{14}CO_2$ production. The amount of ascorbic acid catabolized to CO_2 is dependent upon the ascorbic acid supply. Since there was no difference between treatments, the unsupplemented snakes must have synthesized amounts of ascorbic acid equivalent to those provided to the supplemented snakes.

The second method was an in vitro test that measured the combined activity of two enzymes (Lgulono-gamma-lactofle:NADP oxidoreductase; EC 1.1.1.20 and L-gulono-gamma-lactone:Oxygen oxidoreductase; EC 1.1.3.8) involved in tissue synthesis of ascorbic acid. There was little evidence of ascorbic acid synthesis in the liver of snakes in either treatment. However, the activity of these enzymes was appreciable in the kidneys and was significantly greater in snakes receiving no ascorbic acid supplement. Since the total body requirement for ascorbic acid is presumably met by a combination of tissue synthesis and diet, less tissue synthesis should be needed in the ascorbic acid -supplemented snake.

The third method involved whole-body analysis for ascorbic acid. Approximately 50 jig ascorbic acidlg of snake was found, and there was no difference between treatments. Ascorbic acid intake appreciably in excess of need has been shown to be excreted in the urine. Since supplementation with generous supplies of ascorbic acid did not significantly increase body stores, snakes not receiving ascorbic acid supplementation appeared to store near maximal concentrations as a consequence of tissue synthesis.

During the study, five snakes, two receiving ascorbic acid and three not, showed evidence of oral lesions. These resembled published descriptions of stomatitis in the boa constrictor, with bubbly mucous and slightly swollen subgingival tissue. All lesions healed spontaneously without treatment.

This study involved just two species of reptiles. Thus, it is not appropriate to infer that all reptiles can synthesize ascorbic acid. However, this study provided strong evidence that stomatitis in plains and eastern garter snakes is not a consequence of vitamin C deficiency.

OUR RESPONSIBILITY

Because comparative nutritionists are working in a field with so few established facts, we have a special responsibility to avoid promulgating misinformation and faulty concepts. Equally important is our responsibility to build a solid information base by conducting valid scientific studies. Comparative nutritionists have a host of opportunities for personal aggrandizement, but our most satisfying reward should be the health and welfare of the animals we propose to feed.

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