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Challenges in developing nutrient guidelines for companion animals

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Abstract

The purpose of the present review is to highlight some of the challenges and issues in developing nutritional guidelines for companion animals, and to provide some insights that may influence their future direction. For this purpose, we have chosen to provide a brief historical review of the development of dog and cat nutrient guidelines, and an analysis of current recommendations and of key institutions and bodies (notably the National Research Council) that are influential in defining nutrient guidelines for companion animals. In addition, we have also included a review of current approaches for defining nutritional guidelines for humans and farm animal livestock, as they provide differing perspectives and insights that may be instructive for the future development of nutritional guidelines for companion animals.

Key words: Dogs: Cats: Nutrients: Guidelines

The vast majority of commercially manufactured pet foods (canine and feline) are designed to meet the nutritional guidelines published by one or more of three independent bodies: the National Research Council (NRC; a division of the National Academies of Science, Washington, DC, USA), the Association of American Feed Control Officials (AAFCO, Atlanta, GA, USA) and the Federation Europeenne de l'Industrie des Aliments Pour Animaux Familiers (FEDIAF, London, UK), the umbrella organisation for European National Pet Food Manufacturers Trade Associations. Some national and state authorities also provide guidance or impose specific regulations on the nutritional content and design of pet foods; however, many of these regulations are based wholly, or in large part, on the recommendations of the NRC, AAFCO or FEDIAF. The NRC guidelines will be the main subject of the present review because they are the most influential and arguably the most transparent set of published nutritional guidelines for companion animals, but some reference will also be made to the AAFCO and FEDIAF guidelines.

A brief history of nutrient guidelines for dogs and cats

Since the 1940s, the NRC–National Academy of Sciences has released reports on the nutrient requirements of numerous species of animals. The reports are updated when new information and financial support become available. Although the emphasis has been on the primary agricultural species (poultry, swine, dairy cattle and beef cattle), the nutrient requirements of other species, including companion animals (e.g. dogs, cats and horses), have been addressed. A committee of experts is appointed to develop each of the publications. This process ensures that the information published in NRC reports is unbiased and of the highest technical quality.

The NRC publications for dogs in 1974[(1)] and for cats in 1978[(2)] formed the basis of the nutrient recommendations used by most pet food manufacturers in the 1970s and early 1980s. However, these recommendations were often based on information extrapolated from other species and only provided a single recommendation for all life stages combined.

Research during the 1970s and 1980s expanded our knowledge of dog and cat nutritional needs, and allowed the authors

Abbreviations: AAFCO, Association of American Feed Control Officials; AI, adequate intake; DRI, dietary reference intake; FEDIAF, Federation Europeenne de l'Industrie des Aliments Pour Animaux Familiers; FNB, Food and Nutrition Board; ME, metabolisable energy; MR, minimum requirement; NRC, National Research Council; RA, recommended allowance; RDA, recommended daily allowance; SUL, safe upper limit; UL, tolerable upper intake level.

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of the NRC dog[3] and cat[4] recommendations to address some of the limitations of the previous publications including making separate recommendations for adult maintenance, growth and reproduction. A key development in these publications was an advisory caveat, 'caution is advised in the use of these requirements without demonstration of nutrient availability, because in some cases requirements have been established on the basis of studies in which nutrients were supplied in highly purified ingredients where digestibility and availability are not compromised'; this had a profound impact on how the guidelines were used. Because 'uncompromised' availability of all nutrients could not be assumed or guaranteed in diets comprising typical commercial ingredients (given the nature and diversity of raw materials used), industry and regulators concluded that the NRC recommendations could not be used 'in practice' to support nutritional adequacy claims in pet foods. To resolve this impasse, the AAFCO formed the Canine Nutrition Expert and the Feline Nutrition Expert subcommittee(s) in the early 1990s. These subcommittees comprised representatives from the pet food industry and academia and chaired by a representative of the Food and Drug Administration. The AAFCO, the Feline Nutrition Expert and the Canine Nutrition Expert subcommittees provided industry and regulators a vehicle for translating the recommendations of the NRC based on 'purified diets' into a set of guidelines that could more easily be applied for the practical formulation of pet food and the regulation of 'nutritional adequacy'[5]. However, these guidelines have not undergone a substantive update since the early 1990s and may not reflect more recent scientific reviews of this topic[6] (see below).

In Europe, an additional set of guidelines for dogs and cats has been developed and published since 2000, under the auspices of the FEDIAF. These guidelines were drafted by a subcommittee made up of technical representatives from the main European National Pet Food Manufacturers (London, UK)[7]. The purpose of the FEDIAF guidelines is broadly similar to those developed by the AAFCO, which is to provide industry with a set of guidelines that can readily be used for the practical formulation of pet food. The guidelines play an important role in promoting best practice in the pet food manufacturing industry. There are some differences between the FEDIAF and AAFCO nutrient profiles. In part, this may be a reflection of differences in time frames for revisions and updates, but also reflects differing interpretations of the literature and judgments of what constitutes a 'practical' guideline for any given nutrient. However, the FEDIAF guidelines should be commended for transparency, because they do provide an explanation and rationale for specific recommendations.

National Research Council, nutrient requirements of dogs and cats (2006)

In 2006, the NRC published an update of recommendations made for dogs and cats[6]. The new edition attempts to address many of the criticisms of the previous publications by introducing a new concept, the 'recommended allowance (RA)', which takes account of the natural variation in the bioavailability of nutrients in 'typical' raw materials used in the manufacture of commercial pet foods. As well as combining nutrient requirements of both species in one volume and encompassing new information concerning the requirements for energy and essential nutrients, the new edition includes new chapters on digestive physiology, feeding behaviour, laboratory dogs and cats, physical activity and the environment, diet formulation and processing, and non-traditional food constituents, and provides information concerning the nutrient composition of common pet food ingredients. The result is an increase in the number of pages from a combined total of 153 pages for the two earlier editions to 419 pages in the new edition.

The 2006 recommendations were formulated by an *ad hoc* committee consisting of a chairman and nine other members considered experts in some aspects of the nutrition of dogs and cats. Of these experts, eight were from academic institutions and one was an independent consultant. The committee was assisted by six NRC staff members. Each chapter was initially written by a primary and a secondary author and then was reviewed by all members of the committee. The report was then reviewed by fourteen other pet nutritionists, although the reviewers were not asked to endorse the report.

The recommendations give minimum and maximum amounts or concentrations for each nutrient to facilitate formulating complete and balanced diets for healthy animals. The committee resisted extending the scope beyond the maintenance of health and prevention of disease, and did not address nutrient requirements for animals with disease. Theoretically, any diet formulated to contain more than a minimum and less than a maximum amount or concentration of each nutrient provided in the tables should be complete and balanced for healthy animals. However, making pet food is a complex process, and animals are not uniform. Thus, there are many factors that can affect nutrient requirements, and it is important to recognise the limitations of these NRC recommendations. It is believed that highlighting the limitations and dilemmas that were faced in determining the requirements will encourage further study and help to make current and future recommendations of more practical use.

For each species, tables of minimum and maximum requirements are provided for growth, adult maintenance, and pregnancy and lactation. Methods for calculating the energy requirements of animals and the energy density of foods are also provided.

The 2006 NRC guidelines define the minimum requirement (MR) as the minimal concentration or amount of a bioavailable nutrient that will support a defined physiological state. Then, a safety factor, designed to allow for normal variation in nutrient bioavailability in typical pet food ingredients, is added to the MR to give a RA for foods formulated from normal pet food ingredients. For example, for protein, the MR for maintenance in dogs is 20 g/4184 kJ (1000 kcal) metabolisable energy (ME) and the RA is 25 g/4184 kJ (1000 kcal) ME.

For many nutrients, a MR cannot be established because gradually increasing amounts of nutrient have not been fed to dogs and cats while measuring performance. As a result, the tables, especially those for adult maintenance, have many blank values for MR. However, where an MR has not

been established, a pet food has often been fed to dogs and cats without resulting in signs of deficiency. This allows an adequate intake (AI) to be established, defined as a concentration or amount of a nutrient that had been demonstrated to support a defined physiological state. Because the AI is established using pet food ingredients, a safety factor is not included when an RA is established based on an AI. Thus, it is possible that a diet containing lower concentrations than an RA established from an MR but made from bioavailable ingredients, or a diet containing lower concentrations than an RA established using an AI, may still support a given physiological state. These important possibilities are sometimes not appreciated by the public or regulators.

The 2006 NRC recommendations give a safe upper limit (SUL) for some nutrients, where a SUL is defined as the maximal concentration or amount of a nutrient that has not been associated with adverse effects. These SUL give some indication of how much of a nutrient may be included in the diet safely; however, it is possible that higher concentrations than a SUL may be fed with impunity (e.g. vitamin A in growing puppies) for reasons similar to those given earlier to explain why some animals may be fed less than the RA.

Critical analysis: strengths and weaknesses

(1) The 2006 NRC document represents a substantial improvement from the previous version but has also stimulated some controversy and provides some lessons for the future. It provides a good review of the literature generated since the last edition and provides updated recommendations for growth, maintenance and reproduction. There are also several important new chapters. Nevertheless, the publication has become too expensive and somewhat opaque, which may have limited the outreach of this important document.

(2) The new NRC guidelines clarify the quality of information on which recommendations are based by distinguishing MR from AI. They also allow for differences in the availability of nutrients by distinguishing MR from RA and provide an indication of safe maximum rates of inclusion as a SUL for some nutrients. Unfortunately, there remain many gaps in the tables listing MR, because there has been little research performed during the last 20 years to better determine the essential nutrient requirements of healthy dogs and cats. Most requirements have been established using growth rate as the criterion of adequacy, and there remains little information on the MR for maintenance and reproduction or any other physiological state. There is also comparatively little information on bioavailability; consequently, safety factors are in many instances an educated estimate. Unfortunately, the basis for the size of the safety factor is not always made clear, and the size of the safety factor may represent an overestimate where the authors have erred on the side of safety. As a result, some RA may be higher than needed, e.g. Cu or Zn, and there are many caveats in the footnotes to the tables and in the text.

(3) There is also no distinction between SUL that are known quite precisely from toxicological studies, and SUL that are known less precisely. In the latter situation, higher amounts might be safe, but there are no published reports of feeding higher concentrations with impunity. This lack of clarity has resulted in some controversy because some manufacturers maintain that they have fed concentrations of nutrients above the SUL to cats and dogs without causing illness. The definitions provided in the 2006 publication do not exclude that possibility, but a more recent NRC report published in 2008 that discusses the safety of dietary supplements for horses, dogs and cats[8] clarifies the situation by adding some additional terms: a no observed adverse effect level, the maximum concentration of a substance that is found to have no adverse effects upon the test subject; a presumed safe intake, at which the animal health or production efficiency has not been impaired; a historical safe intake, based on the known levels consumed by wild or domestic animals over long periods of time with no apparent ill effects.

(4) The guidelines provide some recommendations as to how to accommodate factors that affect nutrient requirements other than bioavailability and life stage. Such factors include the energy density of the diet; different amounts of activity, different life stages; the animal's breed; sexual status, body size and body condition; and the measure by which performance or health is assessed. For example, the requirements are reported as amounts per kg of diet, per 4184 kJ (1000 kcal) of ME and per metabolic body weight ($kg^{0·75}$ for dogs and $kg^{0·67}$ for cats) in each table. Unfortunately, presenting recommendations in different formats, together with many caveats in the text and footnotes, makes the recommendations very difficult for both lay people and professional nutritionists to understand.

(5) The 2006 NRC also uses an improved method to estimate the energy density of food compared with that previously recommended. The method recommended previously by the NRC and the AAFCO using modified Atwater factors[3] underestimates the energy density of many pet foods and results in feeding recommendations that are too high, whereas the 2006 NRC method is more accurate because it allows for variation in the digestibility of food.

(6) The 2006 NRC also recognises that pet foods vary widely in nutrient density and emphasises that nutrient density should be ascertained relative to energy (amounts per 4184 kJ (1000 kcal) ME) rather than amounts per kg of diet because energy determines how much food should be consumed to maintain body weight in dogs and cats. The recommendations also assume that the amounts per 4184 kJ (1000 kcal) ME do not change in dogs and cats of different sizes. Most studies have not changed nutrient composition for different sizes of dogs or cats, so there is no reason to suggest that nutrient density should change with size, but there are few data on the allometry of nutrient requirements, and it is possible

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that requirements may vary with metabolic body weight in some physiological states but not in others. Nutrient requirements may vary relative to metabolic body weight for maintenance, for example, but not for growing animals. Furthermore, it is likely that nutrient density may have to increase in sedentary animals requiring very little energy for maintenance and may not need to be as high in working dogs needing more energy. It is important, therefore, that the NRC recommendations should be used only with an appreciation of how all these factors affect nutrient requirements.

Institutional (National Research Council) challenges

The NRC receives no direct financial support for the nutrient requirements series and is dependent, therefore, on sponsorship for each report. There are also restrictions on the proportions of funding that can be accepted from sponsors who could be perceived as having a financial interest in the findings of a report. These financial challenges are the largest impediment to more frequent updates. Fortunately, a portion of the profits from the sale of previous nutrient requirement reports is available as seed money to leverage contributions from sponsors.

With so many species to cover, decisions have to be made about which species take priority for revision. In general, reports that cover species with the greatest economic significance receive more frequent updates than do others, but issues such as national and international priorities and the extent of new information are considered.

The NRC is subject to the US government regulations (e.g. the Federal Advisory Committee Act and the Freedom of Information Act) that affect the work of committee members and staff. In general, these regulations have little impact on the work of committees dealing with nutrient requirements, but they sometimes inhibit flow of information from the public to committee members.

To protect its reputation as an institution that produces reports based on high-quality science and debate and that are, as far as possible, free from external influence and bias, the NRC has well-defined practices that all committees must follow. These practices include reviews of bias and conflict of interest among committee members, public access to information about committee composition and meetings, and protocols for external review of a draft of the report before release. These important measures add to the time required to complete a report (and also to the cost).

Members of all NRC committees serve without compensation (except for reimbursement for the expenses associated with attending meetings). Sometimes the work involved in preparing and writing the draft report and responding to reviewer comments exceeds that which was anticipated. This can lead to delays that can be frustrating for everyone including staff and sponsors.

Although all of the nutrient requirement reports have the same general format and committees are assigned a similar task, each species presents unique challenges. Nevertheless, many challenges are common to all committees. Some of the most significant are discussed below.

While the primary focus of these reports is the establishment of nutrient requirements for specific stages of life and functions, most reports contain additional background material. Examples are the anatomy and physiology of digestive tracts, methodology, and non-nutrient feed additives. Each committee has to wrestle with how much background material to include. Recent reports for several species, such as horses[9] and small ruminants[10], have included far more material than previous editions.

Committees also have to decide on the most appropriate modes of expressing nutrient requirement values. For example, requirements can be expressed as a percentage of the diet (on an 'as is' or DM basis) or as a function of energy (Gross energy (GE), Digestible energy (DE), Metabolisable energy (ME) or Net energy (NE)) and be on a total, digestible or bioavailable basis. Modes of expression most appropriate for one species and stage of life may not be suitable for other situations. In addition to MR, allowances, daily-recommended intakes and SUL are sometimes provided.

Mathematical models are valuable tools in the estimation of requirements and committees have to decide whether a model is appropriate and if so what type (static *v.* dynamic; deterministic *v.* probabilistic/stochastic). Computer programs can be very time consuming to develop and test, and so whether to include a model is a key decision that each committee must make early in its deliberations. The user interface is also an important component.

Feed composition tables are included in the nutrient requirement publications and often take up a significant portion of the committee's time. A national or international database that could be used in all reports would be a great asset.

Dietary guidelines for humans: implications for companion animals

Dietary guidance for humans can be traced back to the British Merchant Seaman's Act in 1835, which suggested lime or lemon juice for sailors to prevent what we know today as scurvy. The UK, The Netherlands, France, Germany and the USA developed dietary recommendations and standards to prevent starvation or to provide the basic needs for military personnel between approximately 1860 and 1900. Generally, these guidelines focused on energy, protein and 'protective foods'. Between 1900 and 1940, there were extensive advancements in the discovery of essential nutrients, particularly vitamins and minerals, as well as a more detailed establishment of dietary requirements and recommendations by the USA and the League of Nations[11,12]. In 1940, the Committee on Nutrition was appointed by the US Department of Defense to assist in nutrition planning with the anticipated entry into the Second World War. This committee evolved into the Food and Nutrition Board (FNB; Washington, DC, USA), which resides in the Institute of Medicine, National Academy of Sciences.

Recommended Daily Allowance (RDA) for energy, protein, two minerals and six vitamins were first published in 1941. By the tenth edition in 1989, there were recommendations for

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eighteen vitamins and minerals and 'safe and adequate daily dietary intake' recommendations for seven others. RDA were defined as 'levels of intake of essential nutrients considered, in the judgment of the FNB on the basis of available scientific knowledge, to be adequate to meet the known nutritional needs of practically all healthy persons'. RDA committees met over 5-year periods, mostly behind closed doors, and published updated dietary recommendations considering new research advances over that period of time.

In the early 1990s, the FNB began to consider a new conceptual approach for the establishment of dietary guidance. A driving force for this was the consideration of nutrient requirements for optimal health or reduction of chronic diseases, not just for prevention of nutrient deficiency diseases. The new concept was reflected in the landmark FNB document, 'Diet and Health: Implications for Reducing Chronic Disease Risk' in 1989, which stimulated consideration of nutrients and disease prevention[13]. In 1994, the Institute of Medicine, with guidance from the FNB, undertook activities that resulted in a new framework for the development of reference values, the dietary reference intakes (DRI)[14].

It was recognised that a single RDA value alone was not sufficient to meet the breadth of the intended reference value needs. In addition to the RDA, values for the estimated average requirement, tolerable upper intake level (UL) and AI were defined and introduced. In addition, the acceptable macronutrient distribution range was developed for macronutrient recommendations. From 1995 to 2004, a large number of nutrient-based reports were published in addition to reports focused on applications of DRI for dietary planning and dietary assessment. In addition, a summary guide 'DRI': The Essential Guide to Nutrient Requirements' for students and end users was published in 2006[15]. There is no intention to produce a complete revision of the DRI. Instead, new committees were only to be convened to consider revisions when new research suggested such a need. The first such panel on vitamin D and Ca has recently published revised DRI for these two specific nutrients (http://www.iom.edu/Reports/2010/Dietary-Reference-Intakes-for-Calcium-and-Vitamin-D.aspx).

There are a large number of limitations in setting the DRI. The primary challenge in setting DRI for males and females of different age ranges, for lactating and pregnant women and for different ethnicities, is a lack of available human data. Many DRI are established based on studies of a few individuals, and the true biological variance around the estimated average requirement is usually unknown. Extrapolation of small amounts of data from (usually) white, young males may not always be representative for other age, ethnic and sex groups. There is a lack of specific, sensitive, functional biomarkers. The use of stable isotopes enhances our ability to make assumptions about metabolism and storage of nutrients, but we are far more restricted as to what can be done compared with what is possible in animal studies. Compliance of human subjects during clinical trials or reliability of dietary recalls is often poor. Many UL are set based on acute toxicity or adverse events and not upon chronic excess dietary exposure. The cost of carrying out a comprehensive dietary requirement study is in the millions of dollars, and no federal funding programmes are in place to support these types of studies. Many federal and state feeding programmes are legally bound to comply with RDA. Since the RDA for a number of nutrients is close to the UL, it is difficult to design dietary programmes that achieve RDA intake levels for all without having some individuals exceed the UL for these nutrients. With the new DRI framework that considers nutrient requirements for chronic disease outcomes, the establishment of specific DRI numbers becomes more difficult.

During the period of 1996–2004, there was a funded 'Standing Committee on the Scientific Evaluation of DRI''. This committee oversaw all of the 'nutrient panels', the 'applications' committee and the 'upper levels' committee to assure that all reports and recommendations were coordinated. The standing committee assured logical and timely movement from report to report. Since then, there has not been continuous federal funding for additional DRI activities. Long-term sustained funding for standing committees for both DRI and the NRC activities and updates of requirements for animals is highly recommended. These committees can help set the priority of species or nutrients to evaluate. The DRI and the NRC processes to establish requirements are costly despite the volunteer effort of hundreds of scientists. Thus, stable funding is sorely needed.

A clear difference between the FNB and NRC work is that humans have varied diets, and it is particularly difficult to control or monitor dietary intakes. The NRC requirements of dogs, cats, rodents and some other species assume that a single feed will provide 100% of the animal's needs. Compliance, or measurement of feed intake, is much easier with these species. In addition, study of males and females of different ages and during reproduction is more easily accomplished with animals. Setting UL for humans is also more difficult than with animals. Both the FNB and the NRC share the issue of lack of acceptable biomarkers. More dialogue between groups may speed the development of better biomarkers of nutrient status and overall health. Enhanced research funding is of critical need to more clearly establish DRI and nutrient requirements of both animals and humans.

Dietary guidelines for farmed livestock: implications for companion animals

In the UK, the Agricultural Research Council, which was created to improve agricultural output and efficiency, is no longer in operation. Its replacement, the Biotechnology and Biological Sciences Research Council, has wider responsibilities, including human medicine. Position shifting has also occurred with the relevant government departments: the Department for Environment, Food and Rural Affairs now replacing the previous Ministry of Agriculture Fisheries and Food. The two earlier champions of the search for Nutrient Requirement Standards are thus gone. The British Society of Animal Science managed the publication of an updated Standard for Pigs[16], but nothing has followed for other species. The 'Feed into Milk' programme (for dairy cows) of the early 2000s has helped forward thinking and practice but aspires more to understanding through modelling than the

setting of requirements. Presently in the UK, there seems a lack of will for updating nutrient requirement standards. European Union initiatives may do better, but it has to be said that with swine (the easiest one), there has been failure even to agree on a common unit for defining energy!

Currently, there appears to be little appetite for seeking the ultimate goal of correctly defined nutrient requirements probably because efforts through the second half of the last century to achieve the same are perceived to be of limited value at the industry application level. The whole concept has taken something of a knock. Deficiency disease is no longer a significant livestock farming problem. Requirements for minerals and vitamins are, on the one hand, seen as out of date with the substantially increased rate of animal productivity since their original determination, while, on the other hand, safety issues have racked up some allowances to now verge upon the profligate. Massive shifts in the genetic composition of farm livestock have had unexpected consequences. Some genotypes need greater amounts of energy and protein to allow their potential to be expressed, while others appear to require a different ratio of nutrients to match a re-balancing of their partition rules. Targets have also shifted, becoming at the same time more diverse. Thus, longevity, welfare and reproductive success have gained in importance over frank daily growth and lactation performance. Furthermore, in many circumstances, the consequences of diet formulation for environmental response are more significant than for animal response. Reduced animal performance may be considered a reasonable price to pay for environmental protection.

For many practitioners, there has been something of a return to empirical methodologies and a move away from the concept of absolute values for nutrient supply. This approach acknowledges that a nutrient requirement is a variable quantity, flexing with purpose (target output), genotype, environment, economic climate and nutrient source (feedstuff). This requires that formulators know the ways and means (equations, algorithms and conceptual frameworks[16]) to calculate for themselves nutrient needs in given, specific and often unique circumstances. The best determination of an animal's optimum nutrient supply will be highly specific (not in the least general). In brief, nutrient requirements will indeed be ever changing with no determinable endpoint of definition, and the guidelines required are not didactic statements but methodologies for deductive (and variable) resolution.

A potentially useful way forward is the use of response prediction models[17,18] to calculate nutrient requirement streams that respond robotically to the automatic measurement of animal performance in relation to chosen targets[19,20].

The idea that published values for nutrient requirement may properly be used as a baseline standard for the adequate nutrition of farmed animals may thus be challenged; such standards may, for specific animal groups in specific circumstances, be either too high, too low or in the wrong balance. Presently in the UK, there is a real possibility that recommendations for fundamentals such as P, protein and essential amino acid concentrations may be set too high.

General discussion

The present review has highlighted different conceptual approaches to the formulation of nutritional guidelines for humans, companion animals and farm livestock, and suggests some changes that could be made in establishing the nutrient requirements of companion animals. In farm livestock, for example, there is an attempt to move away from fixed nutrient requirements to a framework that allows formulators to adjust nutritional values to give a desired outcome (production variable) for specific situations and circumstances. In contrast, nutritional guidelines for humans and companion animals provide fixed absolute values that are designed to provide 'adequate' nutrition for a defined population (e.g. pregnant or lactating women growing dogs). Predicting and modelling responses in dogs and cats to specific nutrients is likely to be more complex, as they are likely to be less uniform and more outbred than livestock; the widely different sizes within the canine species provide an additional level of complexity. For now, there seems to be significant barriers to the development of predictive models for companion animals.

However, a key consideration for future committees is whether to continue with the current paradigm of formulating to ensure 'adequate' nutrition or to follow approaches in human nutrition that have, over recent years, moved the requirement goalposts from how much of a given nutrient is required to prevent deficiency to establishment of the amount of a nutrient required for 'optimal' health or reduction of chronic disease.

The NRC reports on the Nutrient Requirements of Cats and Dogs have a long history and are used throughout the world as a key source of information on the nutritional needs of pets. The frequency of revision and update is, however, a major limitation in keeping the recommendations contemporary. The previous editions of dog and cat guidelines were 20 years old before they were updated in 2006. To our knowledge, there is no plan to update the current 2006 publication, and new research and knowledge will soon make some of the 2006 recommendations out of date; to remain relevant, a mechanism that facilitates more regular updates is needed.

The scale and scope of the most recent revision was significant and had some consequences on the composition of expertise in the committee. Members were selected to provide expertise of specific nutrients, or nutrient groups, and this was balanced with keeping the number of committee members to a workable size. This meant the committee had a broad spread of expertise covering all nutrient groups and classes, but a limited amount of expertise within any group; and this may have limited the level of discourse and ultimately the rigour of decision-making. Evaluating fewer nutrients would allow committees to contain more than one expert for each area and ensure that there is sufficient depth of expertise to facilitate rigorous and informed examination (and resolution) of the critical decisions and recommendations.

Narrowing the scope of future revisions would also enable committees to go into more depth on specific nutrient or nutrient groups. This would allow committees to extend

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their review and recommendations beyond just nutrient requirements and to include an analysis of key knowledge gaps and future research questions.

Scaling down the size and scope of updates would also in part address some of the tensions of committee members being able to balance their jobs with NRC committee tasks.

The scale and scope of the most recent revision was also reflected in an increased size and cost of the publication. Currently, the 2006 publication is not available online or electronically, and this, with the additional high cost of purchasing the hardback edition, may have limited its dissemination. Consideration should be given to publishing future editions in an electronic format (e.g. Portable Document Format), in addition to paper copies; electronic publication would also enable more frequent updates, and numerous enhancements such as hyperlinks to references and other sources of information. On the other hand, frequent updates could create problems for regulatory agencies that use the report to determine diet adequacy. Frequent updates also present challenges to the NRC in ensuring that there is adequate discussion and review of changes; and these factors should to be considered as part of the future publication strategy.

Limiting the scope of future NRC updates would mean that some features of the current publication might be excluded, for example some of the background sections such as the physiology of digestion; or otherwise made available in a different form, for example the feed composition tables could be made available as a database.

While many areas deserve consideration for future reviews, we recommend early consideration for a review of the energy requirements of companion animals. There is considerable debate as to the appropriate energy requirements of 'typical' pet dogs and cats, and this would address an area of current concern that has bearing on the obesity epidemic in companion animals.

Changing to a different model with more frequent updates covering a narrower scope of nutrients would present different challenges, in particular which nutrient(s) to update and when? Adopting the approach employed for human DRI could address this challenge, establishing a standing panel with the remit of deciding when to initiate a new review, and the appointment of 'review' committees. The standing panel would also need to play a role in ensuring consistency in approach and format of publications, and potentially defining conceptual frameworks and recommendations, for example no observed adverse effect level, a presumed safe intake, a historical safe intake, etc. Representation in the standing panel of expertise from human, livestock as well as companion animal nutrition would ensure that there is good awareness of new developments and connectivity to relevant expertise.

It is recommended that 'review' committees should appoint a chairperson with a strong background in dog and cat nutrition, someone with an understanding of the controversial issues. Employees of pet food companies should be considered where relevant, where possible within the rules of the NRC and National Academy of Science, as they can bring a wealth of expertise. This is particularly important when considering the feasibility of formulating diets within narrow ranges of nutrient intake.

Funding and the mechanism of funding future NRC updates is a key issue that needs to be resolved. The NRC is reliant on sponsorship to support publications, and availability of funds was a key factor that contributed to the long-time interval between the last two revisions of the dog and cat nutrient requirements.

While companion animals are the ultimate beneficiary of the NRC recommendations, the pet food industry is a key user of the reports. As one of the main stakeholders, it is fair that the pet food industry is also a key sponsor; however, there are restrictions on the proportions of funding that can be accepted from sponsors who could be perceived as having a financial interest in the findings of a report. This is a legitimate and real concern about how to maintain the high standards and objectivity of the NRC, with the interdependency and potential tensions with the pet food industry. What is clear is that the current approach for support and funding is not likely to address the central question of how to keep the NRC publications on dog and cat nutrient requirements current and relevant. A number of funding models should be evaluated to see how best to address concerns within both the NRC and the pet food industry on future support of NRC reports. Approaches for consideration, but not limited to, should include a tax on pet food, direct donations or grants or the establishment of a foundation.

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References

1. National Research Council (1974) *Nutrient Requirements of Dogs*. Washington, DC: National Academy of Sciences.
2. National Research Council (1978) *Nutrient Requirements of Cats*. Washington, DC: National Academy of Sciences.
3. National Research Council (1985) *Nutrient Requirements of Dogs*. Washington, DC: National Academy Press.
4. National Research Council (1986) *Nutrient Requirements of Cats*. Washington, DC: National Academy Press.
5. AAFCO (2011) *Official Publication*. Atlanta, GA: Association of American Feed Control Officials, Inc.
6. National Research Council (2006) *Nutrient Requirements of Dogs and Cats*. Washington, DC: National Academy Press.
7. FEDIAF (2008) Nutritional guidelines for completet and complementary pet food for cats and dogs. http://www.fediaf.org/self-regulation/
8. National Research Council (2008) *Safety of Dietary Supplements for Horses, Dogs, and Cats*. Washington, DC: National Academy Press.

9. National Research Council (2007) *Nutrient Requirements of Horses*. Washington, DC: National Academy Press.
10. National Research Council (2007) *Nutrient Requirements of Small Ruminants*. Washington, DC: National Academy Press.
11. Harper AE (1987) Evolution of recommended dietary allowances. *Ann Rev Nutr* **7**, 509–537.
12. Erdman JW Jr (1989) Nutrition: past present and future. *Food Technol* **43**, 220–227.
13. National Research Council (US) (1989) *Diet and Health: Implications for Reducing Chronic Disease Risk*, pp. 749. Washington, DC: National Academy Press.
14. Institute of Medicine (2008) *The Development of DRIs; 1994–2004: Lessons Learned and New Challenges (Workshop Summary)*, pp. 180. Washington, DC: National Academy Press.
15. Institute of Medicine (2006) *Dietary Reference Intakes: The Essential Guide to Nutrient Requirements*, pp. 543. Washington, DC: The National Academy Press.
16. British Society Animal Sciences (2003) *Nutrient Requirement Standards for Pigs* [CT Whittemore, MJ Hazzledine and WH Close, editors]. Penicuik: BSAS. bsas@sac.ac.uk
17. Green DM & Whittemore CT (2003) Architecture of a harmonized model of the growing pig for the determination of dietary net energy and protein requirements and of excretions into the environment (IMS Pig). *Anim Sci* **77**, 113–130.
18. Green DM & Whittemore CT (2005) Calibration and sensitivity analysis of a model of the growing pig for weight gain and composition. *Agr Syst* **84**, 279–295.
19. White RP, Schofield CP, Green DM, *et al.* (2004) The effectiveness of a visual image analysis (VIA) system for monitoring the performance of growing/finishing pigs. *Anim Sci* **78**, 409–418.
20. Parsons DJ, Green DM, Schofield CP, *et al.* (2007) Real-time control of pig growth through an integrated management system. *Biosyst Eng* **96**, 257–266.

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