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Current knowledge about the risks and benefits of raw meat–based diets for dogs and cats

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The feeding of RMBDs to dogs and cats has received increasing attention in recent years. The American Animal Hospital Association,[1] AVMA,[2] and Canadian Veterinary Medical Association[3] have adopted statements discouraging the inclusion of raw or undercooked animal-source protein in dog and cat diets. The Delta Society's Pet Partners Program expressed concern that pets in a therapy animal program could be shedding pathogens in the presence of immunocompromised humans and other at-risk human populations. Therefore, they adopted in 2010 a policy that precludes animals that eat RMBDs from participating in their therapy animal program.[4] For each of the organizations, the primary reason indicated to oppose feeding of an RMBD was that potential pathogen contamination of the uncooked meat causes health risks to the pet fed the diet as well as to other pets, human family members, and members of the public in contact with the pet. These statements did not address other potential problems of RMBDs, such as potential nutritional imbalances or other safety issues of the diets (eg, feeding bones); they also did not address the reasons people want to feed these diets or potential benefits of this type of diet.

A major problem in the discussion about potential risks and benefits of RMBDs is the paucity of good data from high-quality studies. Information on nutritional risk or benefit is often from low-quality studies (testimonials, case series, or poor-quality cohort and case-controlled studies).[5] The evidence for infectious disease risks when feeding RMBDs is of better quality and quantity, but few studies have been conducted to compare the risk of feeding RMBDs with that of feeding commercial foods,[6] and no reports have been published on evaluation of the long-term risks and benefits of feeding RMBDs. The lack of consensus and paucity of good data can make it difficult for veterinarians to provide informed feeding recommendations to dog and cat owners.

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Abbreviations

AAFCO	Association of American Feed Control Officials
BARF	Biologically appropriate raw food
RMBD	Raw meat–based diet

The intent of the information reported here is to provide a balanced review of the issue of feeding RMBDs, types of RMBDs, reasons these diets are fed, and potential benefits and risks associated with feeding of RMBDs. The information will also highlight areas in which additional research is needed to better delineate benefits and risks.

Definition of RMBDs

Raw meat–based diets are those that include uncooked ingredients derived from domesticated or wild-caught food animal species and that are fed to dogs or cats living in home environments. These ingredients can include skeletal muscles, internal organs, and bones from mammals, fish, or poultry as well as unpasteurized milk and uncooked eggs. Raw meat–based diets can be divided into 2 main categories: commercial and home-prepared.

The most common forms of commercial RMBDs are fresh, frozen, and freeze-dried diets intended to be nutritionally complete and balanced. These diets are often formulated to meet values listed in the AAFCO Dog or Cat Food Nutrient Profiles, and individual diets may meet values listed for adult maintenance, growth and gestation-lactation, or all life stages. However, some of these foods may be labeled as intended for intermittent or supplemental feeding only, which means that they are not nutritionally complete and balanced. Commercial RMBDs typically are created from recipes developed by or for a company marketing a specific brand of pet food; these commercial RMBDs are made in large quantities in pet food manufacturing facilities or industrial kitchens, then packaged into smaller volumes for purchase and feeding by pet owners. In addition to the fresh, frozen, and freeze-dried commercial diets, another less common form of RMBD is a carbohydrate premix that includes grains, vitamins, and minerals and is intended to have a raw meat protein source added by the pet owner to provide a complete diet.

In contrast, home-prepared RMBDs include a variety of highly publicized feeding regimens, such as BARF (originally defined as bones and raw food but currently referred to as biologically appropriate raw food by supporters),[7] the Ultimate Diet,[8] and the Volhard Diet.[9] Published recommendations for feeding of RMBDs are typically based on opinion and have not been subjected to rigorous peer review. However, a variety of other recipes and programs for home-prepared RMBDs have been developed by general practice veterinarians, trainers, breeders, and owners. Many of the home-prepared RMBDs include by-products (ie, bones and internal organs), even though these ingredients anecdotally appear to be avoided by some owners because of misperceptions about what they are (or are not). Some commercial foods are now marketed specifically as having no by-products. Also, whereas commercial RMBDs are often developed to meet AAFCO nutrient guidelines and are intended (when fed exclusively) to provide sole-source nutrition for a specific life stage of dogs and cats, home-prepared RMBDs are often based on a rotation of ingredients with the belief that this rotational variety will provide (over a prolonged period) a complement of essential amino acids, fatty acids, vitamins, and minerals to pets.[7–9]

Finally, there are a variety of raw dried or freeze-dried pet treats that have bacterial risks similar to those for RMBDs. These include products such as rawhide chews, pig ears, and cattle hooves that have been commercially available for many years but that have now been expanded to include hearts, tracheas, and bull or steer penises (eg, bully or pizzle sticks). Most of the freeze-dried treats (eg, freeze-dried liver treats) are raw. It has been found in multiple studies[10–14] that there is a substantial risk for contamination of these products with *Salmonella* spp and other bacteria, and outbreaks of salmonellosis in humans have been reported.[10–12] These products should also be mentioned when discussing the issues of risks for raw meat–based products.

Owner Motivation for Feeding RMBDs

Proponents of feeding commercial or home-prepared RMBDs often claim nutritional superiority of these diets and important health benefits. Many claims of benefits are largely unproven and not based on scientific evidence, but they appear plausible to well-intending pet owners who want to feed a diet that will optimize health and wellness of their pets. Anecdotal benefits for RMBDs include better palatability of these diets, cleaner teeth from chewing bones as a part of these diets, a shiny coat, and owner perception that they are providing their pet with a more natural diet.

Furthermore, it may be challenging for owners to comprehend the effects of medical procedures, treatments, and disease processes, but provision of food is an easily attainable aspect by which they can directly influence the care and well-being of their animals. What to feed their pets can be just as important, and sometimes more important, than what owners themselves eat. Many pet owners care for their animals as they would a human family member, and the act of feeding for some owners is a way of enhancing and reinforcing the human-animal bond. Owners want to do what is best for their pets, including feeding their pets properly, but the pet food marketplace is confusing and complicated with many opposing viewpoints. Some of the most passionate arguments surrounding pet health and well-being concern the feeding of RMBDs.

A founding premise in popular lay publications and on the Internet regarding RMBDs is that these are the diets that wild, nondomesticated dog and cat species ate during their evolution into pets, which may provide an important rationale for some owners to feed these diets to their dogs and cats.[7,8] Cats have remained obligate carnivores during domestication, and their natural diet includes a range of small prey species such as mammals, reptiles, birds, and insects that can be hunted, captured, and eaten by the cats. Conversely, dogs have adapted to eating an omnivorous diet and can consume a variety of plant and animal products to meet their essential nutrient requirements. However, both cats and dogs are able to digest and metabolize many nutrients provided from plant-based ingredients.[15] Additionally, dogs have undergone an incredible variety of selection pressures resulting in large phenotypic differences from their ancestors and among current breeds.[16,17] In fact, it was reported[18] that there are 36 regions of the genome that differ between dogs and wolves, 10 of which play a critical role in starch digestion and fat metabolism. The authors of that study[18] conclude that these genetic differences in the genome between dogs and wolves and hence the ability to digest starch and fat constituted a crucial step in the early domestication of dogs. Therefore, even if the typical diet eaten by a wild, nondomesticated dog or cat can be considered optimal for reproduction and survival in those animals, in which the lifespan is typically quite short, these diets may not be optimal for domestic dogs and cats living in a home environment, with owners who anticipate that their pets will have long and healthy lives.

The term natural has a specific definition according to the AAFCO.[19] Natural products cannot contain chemically synthesized ingredients, except for trace nutrients, the presence of which must be declared (eg, a label indicating natural with added vitamins, minerals, and other trace nutrients). Nonetheless, the term natural is used by the pet food industry and pet owners in numerous ways and to imply a variety of properties. Despite the difficulty in use of the term natural, some pet owners believe there is a disparity between commercial dry extruded and moist diets and RMBDs. Some authors have suggested that physical and heat processing, rendering, and inclusion of by-products or chemically synthesized additives and preservatives are unhealthy and, in some cases, may cause disease.[7,9,20] The 2007 pet food recall because of melamine contamination and the associated morbidity and fatalities also brought pet food safety to the forefront. Anecdotally, there appears to be a growing number of consumers who are suspicious of large pet food manufacturers. Additionally, recalls of commercial pet foods for bacterial contamination, mycotoxicosis, thiamine deficiency, and vitamin D toxicosis are evidence that feeding commercial dry extruded and moist pet foods is not completely without risk.[21–25]

Finally, proponents of feeding RMBDs claim health benefits for the diets, such as improvement in coat and skin; elimination of breath, body, and fecal odor; improvement in energy, behavior, and immunity; and a reduction in medical conditions including allergies, arthritis, pancreatitis, dental disease, and parasitism.[7–9,26] Although changes may be anecdotally reported by pet owners and veterinarians, potential health benefits have not undergone scientific evaluation. Investigators in a recent study[27] found indications of lower calcium excretion in urine of dogs eating a commercial RMBD, compared with excretion in dogs eating a commercial dry extruded diet, which suggested a benefit of RMBDs for dogs prone to calcium oxalate urolithiasis. However, the RMBD contained half as much calcium, less than a third as much sodium, and considerably more water than did the dry extruded diet, so it is difficult to interpret the importance of these results. Further research regarding all reported health claims is warranted.

Effects of Cooking on Digestibility

Proponents often claim that one of the benefits of RMBDs is increased digestibility because essential enzymes are not destroyed by cooking. Although most dogs and cats do not require exogenous enzymes, studies[28–30] have found improvements of food digestibility in animals fed RMBDs. Digestibility of RMBDs versus dry extruded diets was examined in exotic felids.[28,29] Investigators in 1 study[29] found that RMBDs had significantly higher digestibility for crude protein, but not for fat, energy, or dry matter. In the other study,[28] investigators found numerically higher amounts of dry matter, energy, and protein in RMBDs, but a statistical comparison was not performed. Decreased digestibility in cooked foods is believed to be the result of effects of heat processing on proteins and amino acids.[31–33] A study[30] that involved domestic cats also found significantly higher energy (8.0% higher) and macronutrient (4.6% to 14.3% higher) digestibility of an RMBD, compared with digestibility for a dry extruded diet. The modest improvements in digestibility for the RMBD, compared with the dry extruded diet, may be related to positive effects of the RMBD on digestibility, negative effects of extruded diets in general, or negative effects of the specific extruded diet used in the study. In that same study[30] of domestic cats, there was no significant difference in digestibility between feeding of the RMBD before and after it had been heated in a microwave to ≥ 71°C (≥ 160°F).

Proteins and amino acids undergo substantial physical changes during processing associated with the manufacture of pet foods. Processing conditions, which primarily involve application of heat but also can include pressure and water content, can have variable effects on protein digestibility and amino acid bioavailability. The effects depend on the ingredients, temperature, and type of processing (eg, canning, extrusion used in the production of most commercial dry pet foods, and freezing or freeze-drying that would be performed with commercial RMBDs). In addition, food proteins can react with other food components such as sugars, fats, oxidizing agents, acids, alkalies, polyphenols, and food additives. Heat processing during the manufacture of dry extruded or moist pet foods typically results in the denaturing of proteins and loss of secondary and tertiary protein structure. Processing can increase bioavailability of proteins through collagen breakdown and an increase in exposure to an animal's digestive enzymes, but it also can negatively affect amino acids through proteolysis, protein cross-linking, amino acid racemization, protein-polyphenol reactions, oxidative reactions, and browning or Maillard reactions.[34] The Maillard reaction accounts for the most important losses of amino acids.[35]

Although conventional heat processing can have negative effects on animal tissue proteins, heat processing improves the bioavailability of some plant proteins secondary to denaturing of antinutritional factors. For example, legumes contain trypsin and chymotrypsin inhibitors that impair protein digestion and reduce protein bioavailability.[36] Heat processing denatures these inhibitors and therefore increases protein bioavailability.

Improved digestibility results in less digesta in the colon with less fecal matter. Decreased fecal output has been found in a study[29] of feral cats and in experiments conducted by one of the authors (BAH). Decreased fecal output is perceived as a benefit by some owners. Although nondigestible carbohydrates in the form of fiber are beneficial to the host,[37] undigested dietary protein results in increased amounts of colonic compounds such as ammonia, phenols, indoles, and amines, which can play a role in diseases, such as colorectal cancer.[38] The authors are not aware of any reported studies on the potential harmful effects of undigested dietary protein on colonic health in dogs or cats.

Heterocyclic amines are compounds formed when muscle meat is cooked with a high temperature. Exposure to high concentrations (eg, milligram/gram of food) of these compounds has been associated with cancer in research animals.[39] Concentrations found in both pet and human foods are much lower (nanograms/gram of food), but these concentrations still may have mutagenic activity.[40] The cumulative effects of these compounds on genomic instability and increased sensitivity to tumor promotion in pets and humans require investigation.

Another frequently cited benefit when feeding RMBDs is an improvement in immune function. In experiments conducted by one of the authors (BAH), domestic cats fed an RMBD for 10 weeks had a significant increase in lymphocyte and immunoglobulin production, whereas there were no significant changes over the study period for cats fed a cooked commercial moist diet. In those experiments, it was also found that cats fed the RMBD were fecal shedders of *Salmonella* spp. Higher amounts of exposure to microbes and microbial degradation products, exposure to pathogens, changes in intestinal microflora, or nutritional differences in the diets may have stimulated the immune response detected for cats fed the RMBD. However, potential health benefits and effects of long-term feeding of RMBDs have not been critically evaluated.

Although there is evidence for improved digestibility of proteins in RMBDs, compared with digestibility of proteins in extruded diets, the clinical effects of this difference are unclear and require further study. Effects of

processing for some commercial RMBDs (eg, freeze-dried or carbohydrate premixes) are also not fully understood. In addition, one of the potential effects attributable to differences in processing is an alteration of the gastrointestinal microbiome. Research is needed on differences in the gastrointestinal biome between dogs and cats that are fed RMBDs versus extruded foods (and compared with results for dogs and cats fed home-cooked diets and canned diets as well as effects among various types of RMBDs). The function and role of chronic exposure to bacteria in metabolism and immune function also should be the focus of future studies.

Health Risks

A number of studies have revealed important concerns about nutritional imbalances when RMBDs are not formulated properly, health risks to animals, and public health concerns.

Health risks to pets—Health risks to pets fed RMBDs include nutritional concerns, safety concerns, and other health risks.

Nutritional Concerns

A US study[41] in 2001 revealed that all of the home-prepared and commercial RMBDs tested (3 home-prepared and 2 commercial RMBDs) had multiple nutritional imbalances, some of which could have important adverse effects on the health of the animals. Examples included a calcium-to-phosphorus ratio of 0.20, vitamin A and E concentrations below the minimum detectable value, and a vitamin D concentration nearly twice the AAFCO maximum amount.[41] Authors of a case report[42] of a growing dog fed an RMBD (a commercial carbohydrate premix plus raw ground beef prepared in accordance with instructions on the package label) reported that the nutritionally unbalanced diet resulted in vitamin D–dependent rickets type I and nutritional secondary hyperparathyroidism. In a recent study[43] in Europe, investigators calculated amounts of 12 nutrients (eg, calcium, phosphorus, and vitamin A) for 95 homemade RMBDs being fed to dogs, as reported by the owners. In that study,[43] 57 (60%) diets had major nutritional imbalances. Therefore, there is concern that both commercial and homemade RMBDs may have important nutrient deficiencies and excesses. In addition, even if these diets meet the minimum nutrient amounts and do not exceed maximum amounts, they may not provide an optimal nutrient profile. For example, many RMBDs are high in fat, compared with the fat content of typical dry extruded or moist pet foods. This may improve coat glossiness as perceived by owners, but it may also cause mild to severe gastrointestinal issues in some animals or increase the risk for obesity in others because it is easy to overfeed high-fat diets.

Whether a pet's diet includes raw meat or bones, there are a number of concerns regarding all home-prepared pet foods. It can be difficult to formulate a nutritionally balanced home-prepared diet. Investigators in 3 studies[44–46] have evaluated the nutritional balance of commonly available home-prepared diet recipes. In the 2 studies[44,45] on animals with medical conditions, 94 recipes were evaluated and none had adequate concentrations of all essential nutrients. In one of these studies,[46] investigators evaluated 200 recipes for healthy dogs, and 190 (95%) recipes had at least 1 essential nutrient below AAFCO minimums and 167 (84%) recipes had multiple deficiencies.

Safety risks

In addition to nutritional concerns about RMBDs, other safety issues related to RMBDs are of major importance, particularly risks of contamination with pathogens.[47] Raw meat, whether sold for human consumption, inclusion in commercial RMBDs, or inclusion in dry extruded or moist pet foods, can be contaminated with a variety of pathogens. Although care is used during processing, meat from healthy food animals intended for human consumption may acquire bacterial contamination from the hide, feathers, or viscera during slaughter, evisceration, or processing and packing.[48] A variety of potential pathogens are present in raw meat, including meat intended for human consumption, with *Salmonella* spp having received the most attention for companion animal species and their owners.[47,48] Because freezing and freeze-drying do not destroy all of these pathogens, both home-prepared and commercial RMBDs are at risk of being contaminated with these and other pathogens.

Several reports[6,49–53] have been published on the presence of *Salmonella* spp and other pathogens in commercial and home-prepared RMBDs. Prevalence rates for contamination with *Salmonella* spp in commercial RMBDs ranged from 20% to 48%.[6,50,51] Recently, a *Salmonella* prevalence rate of 21% for 166 commercial RMBD samples was reported,[51] and 18 *Salmonella* serotypes isolated from those samples were resistant to 12 of 16 antimicrobials tested. It is important to mention that commercial dry extruded foods can also become contaminated with *Salmonella* spp and other pathogens. For example, there was a pet food recall when dry extruded pet foods from a single manufacturing plant were linked to 29 human patients identified with *Salmonella enterica* serovar Schwarzengrund infections between 2006 and 2008.[54]

Home-prepared RMBDs were evaluated in 1 study[49] in which 8 of 10 home-prepared raw chicken–based diets fed to pet dogs had positive results when cultured for *Salmonella* spp, whereas none of the commercial dry extruded diets yielded *Salmonella* spp. In addition, there are reports[53,55–58] of racing Greyhounds, sled dogs, guard dogs, and cats with *Salmonella* infections attributable to consumption of contaminated raw meat, including reports of dogs and cats that died from *Salmonella*-related sepsis. It is not surprising to find high rates of contamination with *Salmonella* spp in home-prepared RMBDs because high rates of contamination with *Salmonella* spp can be found for raw meats sold for human consumption. Rates of contamination with *Salmonella* spp differ among studies[59–63] but range from 21% to 44% of chicken samples purchased from retail locations throughout North America. Rates of contamination with *Salmonella* spp are lower for beef and pork intended for human consumption, ranging from 3.5% to 4%.[64,65]

Contamination of RMBDs with other bacteria and pathogens has also been evaluated. Contamination of

RMBDs with *Escherichia coli* was evaluated in 2 studies.[6,41] Nontype-specific *E coli* was found in 143 of 240 (60%) commercial RMBDs but in only 8 of 24 (33%) commercial dry extruded diets and 2 of 24 (8%) commercial cooked moist diets.[6] A 2001 study[41] revealed that 1 of 5 RMBDs tested (both commercial and home-prepared diets) was contaminated with *E coli* O157:H7. Investigators in another study[50] found a prevalence of 20% for contamination of commercial RMBDs with *Clostridium* spp. Other health risks indicated in case reports or case series of animals eating RMBDs include contamination with *Campylobacter jejuni*[52] or *Toxoplasma gondii*[42,66–68] and increased numbers of infections attributable to *Echinococcus multilocularis*,[69] although the latter infection was in dogs fed raw viscera from wild animals and is geographically limited. Meat intended for human consumption is commonly contaminated with a variety of pathogens, including *Campylobacter* spp (prevalence of 29% to 74% in chicken)[59,60,63] and *Listeria* spp (prevalence of 15% to 34% in chicken and 25% to 52% in beef and pork)[60,63,70] Therefore, home-prepared RMBDs made with meats intended for human consumption are at high risk for contamination and can infect both pets and humans.

Proponents of home-prepared diets, including RMBDs, often cite recalls of commercially available dry extruded and moist diets because of bacterial and chemical contamination as a reason that pets should not be fed those types of diets. Contamination of some commercial pet foods with melamine-cyanuric acid in 2007 resulted in dogs and cats with acute kidney injury.[71] That episode was caused by the supplier deliberately adulterating a human-grade food ingredient that was also used in pet food. In response, in part, to this tragedy, the FDA Amendments Act of 2007 was passed to strengthen the food recall process, and food safety legislation has been further strengthened by the FDA Food Safety Modernization Act that went into effect in 2012.[72] A recall is a method of removing or correcting consumer products that are in violation of regulations administered by the FDA. Although those pieces of legislation grant the FDA mandatory authority to initiate a recall in the future, recalls of pet food currently are initiated voluntarily by a pet food manufacturer, although the FDA can request a manufacturer to initiate a recall. The FDA Amendments Act of 2007 requires that manufacturers submit a report to the FDA no later than 24 hours after determining that there is a reasonable probability that the use of or exposure to the food will cause serious adverse health consequences to or the death of animals (or humans), which constitutes a potential class 1 recall.[71,72]

Of 28 recalls and safety alerts because of confirmed or potential contamination of commercially available pet foods with *Salmonella* spp in 2011 and 2012, 17 were for dry extruded pet foods, 1 was for a raw food intended for cats, and 11 were for raw or insufficiently processed treats, especially raw pig ears.[22] The relatively low rate of recalls of commercial RMBDs may be because consumers or veterinarians do not associate illnesses with potential contamination, there is lack of rigorous quality-control testing by manufacturers, or there is a low prevalence of this feeding regimen in the overall pet population and a more limited market share for commercial RMBDs than for dry extruded and moist cooked diets. It is difficult to make an accurate risk assessment from these data because the percentage of pet owners who feed RMBDs (commercial or home prepared) is not known. Investigators of a 2008 study[73] on the feeding practices of pet owners in Australia and the United States found bones or raw foods were provided as part of the main meal to 16.2% of dogs and 9.6% of cats, and another 7.4% of dogs and 0.9% of cats received raw meat or bones as a treat or snack at least once a week. However, it is important to mention that these data were collected prior to the pet food recall of 2007; thus, these percentages may differ if the survey were conducted today. In a study[14] that involved a survey conducted in 2011, 10.8% of 791 pet owners from 44 US states and 6 countries who responded fed a commercial or home-prepared RMBD as a major component of their pet's diet, and 32.9% fed a home-prepared or commercial RMBD as some component of their pet's diet.

Although commercial RMBDs and ingredients are covered by FDA regulations and can be recalled if contamination or other problems are detected, the feeding of contaminated home-prepared RMBDs that include foods intended for human consumption may go undetected because foodborne illnesses in dogs and cats are rarely tracked unless associated with human disease. There are no data on the number of dogs and cats fed human foods that have been recalled, nor the number of dogs and cats that have become ill after eating a contaminated human food. Although data are available on the number of recalls, the lack of data on recalls because of contamination of commercial and home-prepared RMBDs does not mean that such diets are safe.

To assess the true risks associated with feeding RMBDs, research is warranted to provide information that will lead to a better understanding of the potential health consequences of contamination from RMBDs for all those at risk (ie, the dog or cat that eats the food, other animals in the household [or in a kennel, cattery, or clinic], and humans exposed to those animals, to the RMBDs, and to the animals' feces). Although the gastrointestinal tracts of dogs and cats are shorter in comparison with that of humans,[74] there is no evidence that a shorter gastrointestinal tract prevents infection with *Salmonella* spp or other pathogens. Gastric and intestinal pH do not appear to be significantly different between humans and dogs.[75] It is clear that dogs and cats can carry *Salmonella* organisms, but even if future studies find an increase in resistance to clinical salmonellosis, there have been numerous reports[53,55–58] documenting that salmonellosis can occur in both dogs and cats. The prevalence of contamination found in the studies conducted to date suggests that contamination rates of RMBDs are much higher than would be indicated on the basis of the number of recalls, so a better understanding of the potential risks is important.

Some RMBD manufacturers currently use high hydrostatic pressure processing (also called high-pressure pasteurization) in an attempt to reduce risks of pathogens in commercial RMBDs. Although this process can reduce the numbers of many pathogens, it

usually does not completely eliminate them, and bacteria and viruses differ in their susceptibility to this process.[76,77] In addition, there is the potential for the development of resistance to high-pressure pasteurization by bacteria and viruses.[77,78] Therefore, further research is needed on the efficacy of this processing method for reducing the risk from pathogens in commercial RMBDs. Because home-prepared RMBDs are not subject to testing or regulatory oversight, pet owners should be advised of the risks, from pathogens as well as nutritional imbalances, associated with these types of diets.

Other health issues

In addition to the previously mentioned health problems, RMBDs that contain bones (eg, the BARF diet) can potentially result in fractured teeth and gastrointestinal injury. Bones can cause obstruction or perforation of the esophagus, stomach, small intestine, or colon. Bone foreign bodies were present in 30% to 80% of dogs and cats with esophageal foreign bodies.[79–82] Those who promote the feeding of raw bones claim that there are fewer problems with raw bones than with cooked bones[7]; however, to our knowledge, the frequency of obstruction or perforation with raw versus cooked bones has not been evaluated. Research is needed to better understand the frequency of these complications.

Another potential adverse health effect associated with RMBDs was identified in a recent report.[83] Authors of that report[83] identified and described 12 dogs with elevations in serum thyroxine concentration (6 of which had clinical signs of hyperthyroidism) caused by eating an RMBD. All dogs had thyroxine concentrations within the reference range after the diet was changed.

Even in otherwise healthy dogs and cats eating RMBDs, serum biochemical values may deviate from laboratory reference ranges. Serum albumin and cholesterol concentrations were higher than the reference ranges in cats fed an RMBD, compared with concentrations for those fed dry extruded diets.[30] In a study[a] in dogs, those eating an RMBD had significantly higher concentrations of BUN and serum creatinine and a higher Hct, compared with results for control dogs that were assumed to be eating commercial dry extruded diets or moist pet food diets.

Health risks for people—As previously mentioned, raw meats, whether intended for consumption by humans or pets, are frequently contaminated with microorganisms. The most common of these are *E coli*, *Salmonella* spp, *Clostridium* spp, *Campylobacter* spp, and *Listeria* spp.[47,59–65,84,85] In addition, raw meats frequently carry parasites such as *T gondii* and, less frequently, many other parasites that can infect humans or pets.[48,66–68,86–88] In addition to the health risks these pathogens pose for pets, environmental contamination caused by shedding of these organisms by pets is a risk factor for infection of humans.

It is estimated that salmonellosis affects 1.3 million humans/y in the United States, with the cause most commonly linked to contaminated poultry products.[89] *Salmonella* organisms can frequently live as a transient member of the intestinal microflora without causing illness; thus, a human or pet can be a carrier. Direct contact with infected or carrier animals or their feces is a risk factor for salmonellosis in humans,[47,85,89,90] and several studies[49,57,91,92] have found that dogs eating RMBDs are at risk for shedding *Salmonella* spp in their feces. Results of these studies[49,57,91,92] indicate that between 3% and 50% of dogs fed RMBDs intermittently or as a primary diet shed *Salmonella* organisms in their feces. The large variation may be related to whether the diets were home prepared or commercial and the prevalence of contamination of the diets. In 1 study,[92] investigators found that when a single meal of a contaminated commercial RMBD was fed, 7 of 16 dogs shed *Salmonella* spp in their feces for up to 7 days.

Other bacteria also can be of concern for humans who might be exposed to pets shedding bacteria. In a study[91] of dogs fed RMBDs over a 1-year period, the point prevalence rate for extended-spectrum cephalosporinase *E coli* in the feces was up to 45%. Investigators in another study[93] reported on 16 pathogenic *Yersinia enterocolitica* 4/O:3 isolates cultured from the feces of 5 dogs and 2 cats in Finland over a 1-year period; 5 of the animals were known to have eaten raw pork. Although the authors are not aware of any studies conducted to evaluate fecal shedding of other *E coli* or *Clostridium* spp in pets eating raw meats or RMBDs, the high prevalence of contamination of raw meats and RMBDs makes this of major concern for humans exposed to pets eating these diets.

Toxoplasma gondii can be acquired from raw or undercooked meats or from environmental exposure, including contaminated soil or feces. Toxoplasmosis is of greatest danger to people with compromised immune function and to pregnant women and the developing fetus. Toxoplasmosis in a fetus can result in mental retardation, blindness, epilepsy, and death. It can cause severe encephalitis and death in immunosuppressed individuals.[94] Although the prevalence of *T gondii* in retail meats sold in the United States is low, it is sufficient to induce active toxoplasmosis in cats fed raw food samples.[68] Toxoplasmosis can be passed from cats to humans through exposure to oocysts in the cats' feces. The consumption of raw meat significantly increases the seroprevalence of *T gondii* in cats.[95,96] Cats that spend time outdoors, hunt prey, or eat raw meat are more likely to shed oocysts. Such cats can increase the zoonotic risk to their owners, and cats allowed to roam and defecate in gardens or sandboxes may pose a risk to a broader range of people in the surrounding neighborhoods.[94]

The potential risk for human disease has been clearly documented. However, further research is needed to quantify the actual risk and prevalence of disease associated with feeding RMBDs to pet dogs and cats.

Clinical Recommendations

Whether as a means to reinforce the human-animal bond or in response to concerns about the production of commercial dry extruded and moist diets, commercial and home-prepared RMBDs have grown in popularity over the past decade. Proponents of RMBDs claim that they are a safe and natural way to promote animal wellness; these claims are made without long-term supportive evidence and largely ignore the potential

life-threatening consequences to pets and their human caregivers when contaminated RMBDs are fed.

When comparing various types of RMBDs, some general assumptions can be made by veterinary practitioners regarding both commercial and home-prepared RMBDs. Fresh, frozen, and freeze-dried raw animal products are palatable to both dogs and cats and are readily consumed when offered. These types of diets often include higher amounts of protein and fat, with relatively low total carbohydrate and dietary fiber amounts, than are typically found in commercial dry extruded and moist foods. Pets often consume RMBDs without developing any health problems, but sometimes even healthy adult dogs and cats can develop adverse effects, ranging from relatively benign effects (eg, increased colonic fermentation and gas production with higher protein intakes) to more overtly life-threatening concerns (eg, higher fat diet fed to an animal with a history of pancreatitis), as a result of consumption of these diets. Additionally, raw meat has an inherent risk of bacterial and parasitic contamination, and animals that consume RMBDs may pose a risk to other pets and people in the household and surrounding community, including veterinarians and veterinary support staff. All individuals are at risk for infection, but high-risk humans and companion animals should be of particular concern. This includes those who are ill as well as those who are immunocompromised, young, elderly, pregnant, or lactating. Veterinarians may wish to consider instituting procedures regarding pets that eat RMBDs to ensure the safety of other pets and the veterinary staff. These policies should take into consideration the potential legal implications,[97] that there is a period of fecal shedding after eating a contaminated RMBD (up to 7 days),[92] and that common cleaning and disinfection practices do not eliminate *Salmonella* contamination from food bowls.[98]

If a commercial RMBD is formulated to meet AAFCO nutrient guidelines for a particular life stage (ie, growth-reproduction or adult maintenance) of a dog or cat, there should be minimal risk of nutritional inadequacy. However, few manufacturers of raw diets conduct AAFCO feeding trials or digestibility studies on finished products, and manufacturers differ with regard to their attention to quality-control procedures. Thus, the assumption that these diets are truly complete and balanced for long-term feeding relies heavily on the expertise of the individual formulating the original recipe and expectations about the stability and degradation of dietary nutrients. If these diets are manufactured in accordance with current FDA regulations for handling of foods and requirements for microbial testing during food manufacturing and storage,[99] there should be minimal risk of exposure to foodborne pathogens. However, variation in quality-control testing practices or inadequate testing conducted by a manufacturer of a raw food may allow for introduction of pathogens into pet-owning households. Although the FDA has provided a safety guidance document for the manufacturers of RMBDs, manufacturers are not legally required to comply with these guidelines if an alternative approach meets applicable statutes and regulations.[99]

In contrast, home-prepared RMBDs rely heavily on each particular recipe or feeding program as well as the pet owner's interpretation of and compliance with published recommendations, understanding of nutrient requirements for dogs and cats, and understanding of the nutritional value of individual ingredients. On the basis of published diet reviews,[41,43–46] most home-prepared diets (both raw and cooked) are deficient in 1 or more essential fatty acids, vitamins, or minerals or a combination thereof. Although the perceived benefits of home-prepared diets may be reinforced daily to owners through a pet's appetite or coat quality, nutrient deficiencies and excesses in adult animals are insidious and can lead to long-term complications if not detected and corrected. In young growing animals and pregnant or lactating animals, nutrient deficiencies and excesses can cause severe and sometimes life-threatening complications.

Additional studies are needed to provide information that will allow a better understanding of the long-term health effects of RMBDs for dogs and cats. In the absence of reported studies, an animal eating a home-prepared diet (raw or cooked) should undergo an annual physical examination and health screening, which should include serum biochemical analysis (with thyroxine concentrations), hematologic analysis, and urinalysis. Results of routine hematologic analysis and urinalysis will provide veterinary practitioners with a general overview of an animal's health status, but they will not enable practitioners to identify specific nutrient deficiencies or excesses. Thus, owners should be cautioned that nutritionally related disease can mimic other forms of chronic illness. A complete diet history (including all foods, treats, table foods, supplement-type products, and foods used to administer medications) should be obtained from owners at each visit to be able to assess their pet, accurately interpret the results of laboratory tests, and make appropriate recommendations.[100,101] Even when the primary food fed to a pet is not raw, other components of the diet (eg, pet treats such as pig ears, rawhides, or bully sticks; foods intended for human consumption; or foods used to administer medications) may be raw and carry the same inherent risks.

Owners that elect to feed a commercial or home-prepared RMBD should be counseled on the risks to themselves and their pets as a result of this feeding strategy, and the conversation should be documented in the medical record. For commercial foods (regardless of whether they are raw, dry extruded, or moist), it is important to be aware that there is wide variation in quality-control standards among manufacturers of raw or cooked commercial pet foods. Recommendations for selection of a commercial pet food have been summarized (**Appendix**). Unfortunately, the necessary information may not be apparent from reading a label or advertisements. However, asking manufacturers about these topics can be enlightening and useful for selecting a food that is of high quality and not just the one with the best marketing. For home-prepared diets (whether raw or cooked), the authors also strongly recommend consulting with a board-certified veterinary nutritionist to ensure that the owners are using a safe and nutritionally balanced recipe. Additional resources, including a list of board-certified veterinary nutritionists, can be found on the website of the American College of Veterinary Nutrition.[b]

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Appendix

Recommendations for selecting a commercially available pet food.

1. The manufacturer should employ at least 1 full-time qualified nutritionist. Appropriate qualifications are a PhD in animal nutrition or board-certification by the American College of Veterinary Nutrition or European College of Veterinary Comparative Nutrition.
2. The manufacturer should test its diets with AAFCO feeding trials. If AAFCO feeding trials are not conducted, the manufacturer should, at a minimum, ensure that diets meet AAFCO nutrient profiles through analysis of the finished product.
3. The manufacturer should own the plant or plants where the food is manufactured.
4. The manufacturer should practice strict quality-control measures. Examples include certification of a manufacturer's procedures (eg, Global Food Safety Initiative, Hazard Analysis and Critical Control Points, or American Feeding Industry Association); testing ingredients and end-products for nutrient content, pathogens, and aflatoxins; materials risk assessments; and supplier audits.
5. The manufacturer should be able to provide a complete nutrient analysis for any dog or cat food of interest (not only the guaranteed analysis, which is listed on the label, but the average [typical] analysis as well). The manufacturer should be able to provide exact values for all nutrients. This should ideally be provided on an energy basis (ie, grams per 100 kilocalories or grams per 1,000 kilocalories), rather than on an as-fed or dry-matter basis, which does not account for the variation in energy density among foods.
6. The manufacturer should be able to provide the number of calories for any food on any requested weight or volume basis (eg, per gram, per pound, per cup, or per liter).
7. The manufacturer should conduct and publish research in peer-reviewed journals.

Recommendations are on the basis of information included in the nutritional assessment guidelines published by the American Animal Hospital Association[100] and the World Small Animal Veterinary Association.[101]