Timely Topics in Nutrition

Facilitative and functional fats in diets of cats and dogs

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In human health and nutrition, the concept of good fats and bad fats is typically used, especially with respect to dietary risk factors for coronary artery diseases and stroke. This concept originated with the notion that there are 2 forms of cholesterol that, for the sake of simplicity, have been referred to as good and bad. The concept has now been extended to include other dietary fats that may also be associated with increases in cholesterol concentrations.

Dietary fats, including cholesterol, are transported in the blood as lipoprotein complexes. They include LDLs and HDLs.[1] Because LDL, which transports cholesterol into tissues, is involved in the formation of atherosclerotic plaques in humans, it is considered by health professionals to be the bad form of cholesterol. This is especially the case when there is an overabundance of cholesterol that can become deposited in arteries, which results in atheromatous lesions. By contrast, HDL has the capacity to transport cholesterol away from tissues and is thus considered to be the good form of cholesterol. The amount of cholesterol each of the lipoproteins carries, relative to the total amount of cholesterol, partially determines the amount of risk that an individual may have for developing atherosclerosis, coronary artery disease, or stroke. Thus, for humans, fats containing LDL cholesterol are bad fats and fats containing HDL cholesterol are good fats.

Other than cholesterol per se, dietary fats containing specific fatty acid types are also considered to be bad or good for humans, depending on whether they have been associated with increases or decreases in total plasma cholesterol concentrations.[2] Fats that predominantly contain saturated fatty acids are referred to as saturated fats, whereas those containing high proportions of polyunsaturated fatty acids are termed polyunsaturated fats. Saturated fats from animal and some plant sources that typically increase cholesterol concentrations are examples of bad fats. By contrast, good fats generally include polyunsaturated fats, containing omega-6 fats from oilseeds that typically lower plasma cholesterol concentrations. Polyunsaturated omega-3 fats from marine sources typically decrease inflammatory processes and blood pressure[2,3] and also result in several other desirable effects; they are also considered good fats.

ABBREVIATIONS

LDL	Low-density lipoprotein
HDL	High-density lipoprotein
CLA	Conjugated linoleic acid
LA	Linoleic acid
ALA	α-Linolenic acid
DHA	Docosahexaenoic acid
AA	Arachidonic acid
EPA	Eicosapentaenoic acid
DPA	Docosapentaenoic acid

In general then, polyunsaturated fats are considered to be good fats.[2] Even CLA, a type of polyunsaturated fatty acid, is considered by some to be a good fat, and researchers continue to investigate its effects. It has been proposed[4,5] that CLA may help promote lean body mass or that it may even have antitumorigenic effects. By contrast, trans-fatty acids, even though they are unsaturated, are metabolized in humans in a manner similar to that for saturated fats and are generally considered to be bad fats.[6-10]

Finally, monounsaturated fats, such as oleic acid, are fairly neutral with regard to their effects on cholesterol. However, in some circumstances (ie, the Mediterranean diet), they have their proponents.[11]

The reality is that the overall risk of heart disease for humans is not as simple as this brief summary may indicate. However, suffice it to state that the good fats–bad fats concept is a handy way for humans to keep track of dietary habits and risk of heart diseases, and it can be used in discussions with health care providers. As such, it is a useful concept.

Good Fats and Bad Fats for Dogs and Cats

Although the concept of good and bad fats is appropriate for human health, dogs and cats are able to consume both types of fats in their diets without undue risk of coronary artery diseases, heart attacks, or strokes to which humans succumb. The simplified reason for this is that they have more good cholesterol (HDL) than bad cholesterol (LDL) to begin with, no matter what types of fat they consume. Second, in contrast to humans, dogs and cats typically are resistant to the development of hypercholesterolemia and atherosclerosis, even when they consume amounts of dietary fat that would typically turn human blood into sludge.

The fact that good cholesterol concentrations are higher than the concentrations of bad cholesterol is part of the mechanism that protects them from cardiac diseases that may affect humans.[12] In addition, although saturated fats (and possibly trans fats) may cause modest increases in blood cholesterol concentrations in dogs, these dietary components do not appear to impart any increased risk of arterial diseases in dogs, which is in contrast to their effects in humans. Thus, it is not advantageous to classify the various types of fats as good or bad in dogs or cats, although definitive data for cats (other than the fact that cats have high HDL cholesterol concentrations) have not been obtained. In view of these metabolic differences, it is proposed that the types of dietary fats for dogs and cats should be classified as functional or facilitative, rather than good or bad, respectively.

Facilitative Fats

Fat enhances palatability and increases the acceptable textures of foods.[13] Adding fats to improve palatability indicates the manner in which fats can be facilitative because they help ensure the intake of the necessary calories for an animal's well-being. Beef tallow, primarily composed of saturated and monounsaturated fatty acids, is one of the most palatable fats for dogs and cats. Thus, although tallow would be considered a bad fat for humans, it should not be considered as a bad fat for companion animals; instead it is facilitative. In dogs and cats, the amount of tallow that may be fed without imposing a health risk would likely be detrimental to humans when consumed on a daily basis. Dogs and cats readily use such types of fat (ie, saturated fats) through a process known as β-oxidation, which uses oxygen and generates chemical energy in the form of ATP to fuel other metabolic processes.

Additionally, the saturated fat in tallow is facilitative for dogs and cats in that it contributes a high-calorie fuel to the body to provide energy for work, regulation of body temperature, growth, reproduction, or simply survival.[13] Saturated fats are also facilitative because they can be stored in adipose tissues for future mobilization and used for energy when needed. Facilitative fats can be found in relatively large amounts in diets of dogs and cats, and they do not typically pose a health risk, except perhaps with respect to obese animals that are fed excessive amounts of high-fat diets that contain too many calories.

One additional way in which fats are facilitative is that they assist in the proper digestion and absorption of dietary fat-soluble vitamins from mixed micelles in the gastrointestinal tract.[13] Because fats and fat-soluble vitamins are insoluble in water, they must first be emulsified into smaller droplets by dispersion with bile salts so that digestive lipases can break them into digestible forms for absorption. Dietary fats facilitate the absorption of fat-soluble vitamins. It is of interest that one of the problems with the synthetic fat substitute,

sucrose polyester, which is used in some food products prepared for humans, is the fact that absorption of vitamins A and E is decreased when too much of the substitute is consumed. The fat substitute binds the fat-soluble vitamins in such a way that neither component is digested or absorbed. Thus, the facilitative nature of dietary fats plays an important role in nutrition with regard to vitamins.

A facilitative fat improves palatability and increases the acceptable texture of foods, is a dense source of dietary calories and energy, promotes the absorption of fat-soluble vitamins, can be found in reasonably large amounts in diets formulated for dogs and cats, or has a combination of these characteristics. Included in the facilitative fats are dietary saturated fats such as palmitic and stearic; oleic, a monounsaturated fatty acid; and trans-fatty acids (**Appendix**). These fats do not promote increases in cholesterol concentrations per se in dogs and cats as they do in humans. Although they may be bad for humans, they are simply facilitative in dogs and cats.

Functional Fats and Fatty Acids

The first functional fatty acid discovered was LA, an 18-carbon, omega-6 fatty acid. It was found to be an essential dietary component necessary for growth and prevention of skin lesions in dogs and other animals.[14,15] Both omega-6 and omega-3 fatty acids are essential. This is attributable, in part, to the fact that they cannot be synthesized by mammals. Also, both types of omega fatty acids can be converted to longer-chain polyunsaturated fatty acids that have additional essential functions. Thus, certain omega-6 and omega-3 fatty acids serve as precursors of the eicosanoids, which are powerful physiologic mediators of cell functions. These findings have added new complexities to the classification of functional fatty acids. In contrast to facilitative fats, only modest amounts of functional fats need to be included in the diet to meet tissue needs.[13]

Functional fatty acids that are also dietary essential components are all polyunsaturated and have an important methylene-interrupted double-bond sequence in the molecular structure (**Figure 1**). It is this methylene-interrupted sequence that imparts the essential characteristic to these fatty acids, which
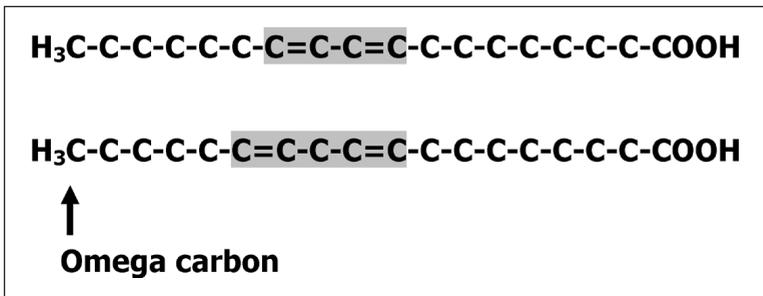

Figure 1—Illustration of the conjugated carbon-carbon double-bond pattern (-C-C=C-C=C-C-) characteristic of CLA isomers (top) and the methylene-interrupted carbon-carbon double-bond pattern (-C-C=C-C-C=C-C-) characteristic of essential fatty acids (bottom). Hydrogen atoms have been omitted, and the omega carbon has been indicated for clarity (arrow). The methylene-interrupted double-bond sequence is unique to the molecular structure of the essential fatty acids, such as LA and ALA.

include LA, ALA, and, for certain physiologic conditions, DHA and AA. Eicosapentaenoic acid has the requisite double-bond sequence and is a functional fatty acid, but there is no evidence of which the author is aware that EPA is essential because it can be synthesized from its precursor (ALA) in dogs. However, limited information is available in cats with regard to synthesis of EPA. By contrast, CLAs may also fit into the functional category as a result of their specific effects in companion animals. However, CLAs do not have the requisite methylene-interrupted sequence and thus are not dietary essential fats. Finally, medium-chain fatty acids are neither polyunsaturated nor essential, but they may be functional in some conditions.

Some Functions of Functional Fats

A functional fat is usually, but not always, an essential fatty acid or derived from an essential fatty acid, participates in an important structural or functional cellular process, or is converted to an important derivative that regulates cell function. Functional fats in dogs and cats include the essential fatty acids LA and ALA. These are important for growth, development, reproduction, and maintenance of healthy skin.[13] Functional fats are involved in numerous processes, so no attempt will be made to delineate all the important functions of specific fatty acids elucidated at this time.

Linoleic acid, an omega-6 fatty acid, is the earliest discovered example of a functional fat. It has a role in ensuring healthy skin as well as in inflammatory skin disorders. In healthy skin, phospholipid ceramides containing LA are extruded as intercellular lamellar granules from epidermal keratinocytes, which enhance cell cohesion and impart an effective water barrier to the epidermis.[16,17] Because LA is directly involved, dogs with skin disorders of a dry, dull coat and scaly, nonpruritic lesions generally respond to dietary supplements of vegetable oils, such as corn or sunflower oils, that are rich in LA. There is evidence that the omega-3 fatty acid, ALA, may also contribute to an effective transepidermal water barrier, but it has been reported[18] that ALA provides a sparing effect on LA, resulting in the accumulation of additional LA that, in turn, may be incorporated into ceramide fractions in the skin.

Long-chain fatty acids that can be derived from LA and ALA also have specific functions. Arachidonic acid is derived from LA, and it functions in myriad ways, depending on the cell type in which it is incorporated. Similarly, EPA, an omega-3 fatty acid, can be synthesized from ALA. Functionality of these 2 long-chain fatty acids can be found in certain skin disorders in which inflammation is a component of the primary problem. In these conditions, EPA, which is synthesized from ALA or provided in the diet, provides a functional anti-inflammatory benefit.[19,20] When EPA is incorporated into the cell membrane, it can serve as a precursor for eicosanoids that are less potent mediators of inflammation, which helps shift the balance away from the more potent mediators synthesized from the omega-6 fatty acid, AA.[21] Thus, substitution of EPA for AA in the cell membrane can help control the inflammatory response. This modification is most helpful in

animals with conditions, such as inflammatory skin disease or osteoarthritis, characterized by an overabundance of inflammatory mediators. Clinical evidence for this effect in skin disorders was reported in a study[22] in which dogs with pruritic skin disease were provided diets supplemented with high amounts of n-3 marine fish oil (66 mg/kg of body weight/d [30 mg/lb of body weight/d]) for a 6-week period. At the end of that study, dogs consuming the supplemented diet had a significant reduction in pruritus as well as improvements in skin and coat character.

Another example of a functional fatty acid derived from its shorter precursor is DHA. Docosahexaenoic acid can be synthesized from ALA and is found in neurologic tissues, including the retinas. In fact, DHA comprises up to 55% of the total fatty acids in the rod outer segment cells of the retinas. In addition, DHA in retinal cells appears to be tenaciously conserved or recycled as these cells are replaced.[23] This fatty acid has an important role in retinal function by helping translate light energy into the neurologic signals involved in vision.

In a study[24] conducted by my laboratory group, we determined that adult dogs fed supplemental amounts of ALA accumulated DPA in plasma phospholipids but did not accumulate DHA in a similar manner. In dogs, the retinas can synthesize DHA from DPA. Thus, we hypothesized that DPA may be an intermediate that is subsequently transported to neurologic tissues and converted to DHA.[24] Analysis of this finding also suggested that the retinas (and presumably other neural tissues) of dogs synthesize and use DHA in a manner similar to that in other mammalian species and that plasma DPA provides substrate for such synthesis. Because DHA is an omega-3 fatty acid essential for vision, a direct dietary source of it or its 18-carbon precursor is necessary during gestation and nursing for normal neural development in fetal and neonatal dogs.

Another study[25] conducted by my laboratory group compared the effects of a control diet containing low amounts of omega-3 fatty acids with diets containing increased amounts of ALA from linseed oil or DHA from fish oil. The diets were fed to female dogs beginning at the time of breeding, during gestation and parturition, and throughout nursing until the puppies were weaned. After weaning, the puppies were also provided the same diets as those consumed by their dams. Inclusion of modest amounts of fish oil containing DHA is more effective than inclusion of high amounts of dietary ALA for improving the response (as measured by use of electroretinography) of the eyes of 12-week-old puppies born and nursed by these dams. We also found that puppies consuming the diet supplemented with DHA consistently had improvements in sensitivity to light (as measured by a-wave amplitudes, response times, and response thresholds of the electroretinograms) and had the largest increase in amplification of the cascade of molecular events necessary for visual function. By contrast, puppies fed the diet rich in ALA (the DHA precursor) had some improvement in sensitivity to light, but this was generally not equivalent to the improvements seen in the puppies consuming the diet supplemented with DHA.

However, puppies fed ALA-supplemented diets did accumulate DHA in their plasma phospholipid fraction, although the ability to do so was lost after the puppies were weaned.

It should be mentioned that an amount of ALA 10 times greater than the amount of DHA was needed for the ALA effects to be evident. Consequently, it cannot be determined from that study[25] whether ALA can be specifically substituted for DHA. Even assuming this to be possible, the quantity of ALA needed would likely be too high to be of practical value. Also, because n-6 and n-3 fatty acids both compete for the same enzyme systems, the role that the dietary LA-to-ALA ratio may have on subsequent conversion of ALA to DHA is unclear. However, there is a clear role for DHA in the visual processes of dogs. As such, DHA is a functional fatty acid and conditionally essential for growing and developing puppies.

Analysis of data from that study[25] clearly indicates that feeding diets enriched in DHA to dams during gestation and lactation and to puppies after weaning results in the accumulation of DHA in plasma lipids of both dams and puppies. This finding is associated with improved neurologic development, as indicated by the electroretinography response. Additional evidence has also emerged that indicates diets or products containing supplemental DHA may also improve memory or learning abilities of young dogs.[a,b] Considered together, these findings will help clinicians and researchers understand dietary modifications used to enhance the performance of working and companion dogs, especially those used as seeing-eye dogs, sentry dogs, guard dogs, or dogs used in field trials. Improvements in neurologic development may also play a role in enhancing the human-animal bond by enabling animals to respond more efficiently to obedience training and improving their ability to learn activities that require sensory input.

Clinical Summary

Dietary fats in foods formulated for pets can be classified as facilitative or functional, rather than good or bad as described for humans. This results from the fact that dogs and cats are more resistant to cholesterol-increasing effects of certain types of fats that are classified as bad fats for humans. Thus, the concept of good fats and bad fats is not particularly appropriate for dogs or cats. The only exception is when the total amount of fat in a diet is so large that it would place an animal at risk for obesity and obesity-associated problems.

Saturated fats and trans fats may be problematic for some humans. However, for dogs and cats, these fats enhance palatability, improve the texture of foods, provide energy, and aid in the digestion of fat-soluble vitamins, similar to the roles for monounsaturated fats in these species. All of these fat types can be found in reasonably high amounts in complete and balanced diets formulated for dogs and cats. By comparison, polyunsaturated fats are, as a group, functional fats. Functional fats provide for healthy skin and coat, promote health of the gastrointestinal tract and renal system, ensure adequate reproductive performance, control inflammation, and play an important role in neurologic development. Only small amounts of functional fats are required in the diet, and some can be synthesized from shorter precursors. However, providing some preformed long-chain forms of these fats appears to be conditionally essential, especially for certain life stages, such as growth and development, and processes, such as reproduction. This is especially the case for DHA, which is converted slowly and inefficiently from its shorter precursor, ALA, and for AA in cats in which conversion from LA is modest at best.

a. Reynolds AJ, Waldron MK, Wilsson E, et al. The effect of long-chain PUFA supplementation on mental stability, problem solving ability, and learned pattern retention in young growing dogs (abstr), in *Proceedings*. Nestlé Purina Nutrition Forum, 2005;Poster 19.

b. Kelley RL, Lepine AJ, Burr JR, et al. Effect of dietary fish oil on puppy trainability (abstr), in *Proceedings*. Preconf Workshop 6th Int Soc Study Fatty Acids Lipids Cong, 2004;51.

References

1. Gotto AM Jr, Pownall HJ, Havel RJ. Introduction to the plasma lipoproteins. *Methods Enzymol* 1986;128:3–41.

2. Hu FB, Manson JE, Willett WC. Types of dietary fat and risk of coronary heart disease: a critical review. *J Am Coll Nutr* 2001;20:5–19.

3. Leaf A, Weber PC. Cardiovascular effects of n-3 fatty acids. *N Engl J Med* 1988;318:549–557.

4. Blankson H, Stakkestad JA, Fagertun H, et al. Conjugated linoleic acid reduces body fat mass in overweight and obese humans. *J Nutr* 2000;30:2943–2948.

5. Song HJ, Sneddon AA, Heys SD, et al. Induction of apoptosis and inhibition of NF-kappa B activation in human prostate cancer cells by the cis-9, trans-11 but not the trans-10, cis-12 isomer of conjugated linoleic acid. *Prostate* 2006;66:839–846.

6. Mozaffarian D, Pischon T, Hankinson SE, et al. Dietary intake of trans fatty acids and systemic inflammation in women. *Am J Clin Nutr* 2004;79:606–612.

7. Willett WC, Stampfer MJ, Manson JE, et al. Intake of trans fatty acids and risk of coronary heart disease among women. *Lancet* 1993;341:581–585.

8. Lichtenstein AH, Ausman LM, Jalbert SM, et al. Effects of different forms of dietary hydrogenated fats on serum lipoprotein cholesterol levels. *N Engl J Med* 1999;340:1933–1940.

9. Turpeinen AN, Wübert J, Aro A, et al. Similar effects of diets rich in stearic acid or trans-fatty acids on platelet function and endothelial prostacyclin production in humans. *Arterioscler Thromb Vasc Biol* 1998;18:316–322.

10. Ascherio A, Willett WC. Health effects of trans fatty acids. *Am J Clin Nutr* 1997;66(suppl 4):1006S–1010S.

11. Gardner CD, Kraemer HC. Monounsaturated versus polyunsaturated dietary fat and serum lipids. A meta analysis. *Arterioscler Thromb Vasc Biol* 1995;15:1917–1927.

12. Bauer JE. Lipoprotein-mediated transport of dietary and synthesized lipids and lipid abnormalities of dogs and cats. *J Am Vet Med Assoc* 2004;224:668–675.

13. National Research Council. Fats and fatty acids. In: *Nutrient requirements of dogs and cats*. Washington, DC: National Research Council, National Academy of Sciences, 2006;81–110.

14. Hansen AE, Wiese HF. Fat in the diet in relation to nutrition of the dog. I. Characteristic appearance and changes of animals fed diets with and without fat. *Texas Rep Biol Med* 1931;9:491–515.

15. Burr G, Burr MM. A new deficiency disease produced by the rigid exclusion of fat from the diet. *J Biol Chem* 1929;82:345–367.

16. Elias PM. The special role of the stratum corneum. In: Fitzpatrick TB, Eisen AX, Wolff K, et al, eds. *Dermatology in general medicine*. 3rd ed. New York: McGraw-Hill Book Co, 1987;342–346.

17. Freinkel R. Lipids of the epidermis. In: Fitzpatrick TB, Eisen AX, Wolff K, et al, eds. *Dermatology in general medicine*. 3rd ed. New York: McGraw-Hill Book Co, 1987;191–194.

18. Rees CA, Bauer JE, Burkholder WJ, et al. Effects of dietary flaxseed and sunflower seed supplementation on normal canine

serum polyunsaturated fatty acids and skin and hair coat condition scores. *Vet Dermatol* 2001;12:111–117.

19. Bauer JE. The potential for dietary polyunsaturated fatty acids in domestic animals. A*ust Vet J* 1994;71:342–345.

20. Okuyama H, Sakai K. Effects of dietary oils with extreme ω3/ω6 ratios—selective incorporation and differential catabolism. *World Rev Nutr Diet* 1991;66:195–204.

21. White P. Essential fatty acids: use in management of canine atopy. *Compend Contin Educ Small Anim Pract* 1993;15:451–457.

22. Logas D, Kunkle G. Double-blinded crossover study with marine oil supplementation containing high-dose eicosapentaenoic acid for the treatment of canine pruritic skin disease. *Vet Dermatol* 1994;5:99–104.

23. Fliesler SJ, Anderson RE. Chemistry and metabolism of lipids in the vertebrate retina. *Prog Lipid Res* 1983;22:79–131.

24. Bauer JE, Dunbar BL, Bigley KE. Dietary flaxseed in dogs results in differential transport and metabolism of (n-3) polyunsaturated fatty acids. *J Nutr* 1998;128:2641S–2644S.

25. Heinemann M, Waldron MK, Bigley KE, et al. Long-chain (n-3) polyunsaturated fatty acids are more efficient than α-linolenic acid in improving electroretinogram responses of puppies exposed during gestation, lactation, and weaning. *J Nutr* 2005;135:1960–1966.

Appendix

Dietary sources and fatty acids for facilitative and functional fats of dogs and cats.

Source*	Facilitative	Functional
Animal fats	Tallow	
	Lard	Contains small amounts
Marine oils	Fish oils	Fish oils
		Purified algal oils
Vegetable oils	Palm oil	Corn oil
	Palm kernel oil	Soybean oil
		Sunflower oil
		Canola oil
		Flaxseed oil
		Others†
Primary fatty acid types	Saturated Myristic acid Palmitic acid Stearic acid	Omega-6 LA AA
	Monounsaturated Oleic acid	Omega-3 ALA EPA DHA
	Hydrogenated fats including trans fatty acids	CLA and medium-chain triglycerides

*Oil sources that contain functional fats also contain various amounts of facilitative fats such as fish oils. However, oil sources that contain facilitative fats are not typically rich in functional fatty acids. †Includes cottonseed, peanut, sesame, black currant seed, and borage oils as additional, but not exhaustive, examples.