Pet owners often perceive skin and coat condition as an indicator of the optimal nutrition and well-being of their animals. Although several dietary factors are important in this regard, the EFAs have a critical role. Indeed, one of the hallmarks of EFA deficiency in animals is a matted coat and unkempt appearance. Other clinical signs of EFA deficiency include poor growth; infertility; a thin, discolored coat; scaly skin; sebaceous gland hypertrophy with increased viscosity of sebum; increase in epidermal turnover rate; increase in DNA synthesis in keratinocytes; weak cutaneous blood vessels that are easily ruptured; decrease in wound healing; and increase in transepidermal water loss. Thus, providing dietary EFAs ensures fluidity of membranes, helps maintain the cutaneous water permeability barrier, and supplies fatty acid precursors of eicosanoids and other important physiologic mediators for cell function, all of which contribute in some manner to health of the skin and coat.

The epidermal water barrier function of skin depends on the LA (18:2n-6) content of the cellular phospholipid fraction known as ceramides. In normal healthy skin, ceramides containing LA are extruded as intercellular lamellar granules from epidermal keratinocytes, which enhances cell cohesion and imparts the epidermis with an effective water barrier. Because LA is directly involved, many instances of dry, dull coats and scaly, nonpruritic skin disorders in dogs generally respond to dietary inclusion of vegetable oil supplements rich in this fatty acid. Little information has been published on the effects that EFA supplementation beyond a minimal requirement has to improve the skin and coat when there is no preexisting deficiency. Nonetheless, there is considerable interest in optimizing lipid nutrition in dogs by choosing an appropriate dietary balance of fatty acids.

Studies in dogs have revealed that composition of fatty acids in serum and cutaneous tissues can be modified by dietary supplementation. In 1 study, investigators evaluated the effects of feeding a diet that contained increased amounts of ALA for 36 days and found that there was relative enrichment of the content of this fatty acid in serum and skin samples. In addition, significantly lower transepidermal water loss and an increased sheen of the dogs’ coats were reported, although this latter finding was not significantly different from that for the other diets fed during the study. Complete lipid profiles of diets used in that study were not reported, so a thorough comparison of the diets used could not be performed. However, because linseed oil provided the source of high ALA content in the test diet, it suggests that ALA may also function similar to LA via incorporation into the ceramide layer of the epidermis, thereby supporting more desirable skin and coat scores. However, it should be mentioned that whereas linseed oil contains approximately 53% ALA, it also contains approximately 13% LA.

Extending this initial finding, our laboratory group conducted a study to compare linseed (rich in LA and ALA) and sunflower seed (rich in ALA) supplements in clinically normal dogs fed a basal diet. Significant short-term improvements in skin and coat scores were found for both groups. It was reported that both supplements specifically led to increased amounts of circulating LA, thereby supporting the possibility of subsequent incorporation of LA into the ceramide fractions of the epidermis, which would result in more desirable skin and coat scores. In addition to this direct dietary effect of LA, we hypothesized that the ALA in the diet may have provided a sparing effect on the conversion of LA into other lipid metabolites, which thereby allowed additional accumulation of LA.

Additional support for the importance of LA in skin health was obtained when serum fatty acids from atopic dogs were found to be significantly reduced in LA-deficient dogs, compared with dogs that were not deficient. Impaired absorption of LA may have existed as a result of decreased serum triglyceride concentrations typical in atopic animals. Furthermore, investigators found in another study that cutaneous fatty acids in dogs with seborrhea also have a lower LA content. However, it should be mentioned that despite the aforementioned findings, improvements may have simply been the result of an overall increase in dietary total fat content independent of fat type. Nonetheless, it appears that animals with noninflammatory clinical signs of EFA deficiency include poor growth; infertility; a thin, discolored coat; scaly skin; sebaceous gland hypertrophy with increased viscosity of sebum; increase in epidermal turnover rate; increase in DNA synthesis in keratinocytes; weak cutaneous blood vessels that are easily ruptured; decrease in wound healing; and increase in transepidermal water loss. Thus, providing dietary EFAs ensures fluidity of membranes, helps maintain the cutaneous water permeability barrier, and supplies fatty acid precursors of eicosanoids and other important physiologic mediators for cell function, all of which contribute in some manner to health of the skin and coat.

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skin problems can benefit from the use of a human-grade vegetable oil that contains both LA and ALA fatty acids. It remains to be determined whether some specific amount of an EFA or one of its metabolites in excess of the minimal requirement will provide optimal skin and coat conditions in dogs.

**Fatty Acids and Inflammatory Skin Disorders**

When inflammation is a component of the problem, dietary supplementation with n-3 fatty acids (and some n-6 fatty acids) may be beneficial. The anti-inflammatory response of fatty acids and their use in prevention and treatment of chronic diseases have been evaluated primarily in mice, rats, humans, and horses, as well as in vitro, but few investigations have been conducted in dogs. Furthermore, most clinical investigations on this topic have not provided precise amounts and types of the dietary fatty acids consumed. Studies designed to more clearly define specific effects of dietary EFAs are needed to enhance this area of investigation in veterinary medicine.

**Effects of n-3 Fatty Acids**

The n-3 fatty acids have increasingly gained popularity as a means of treatment for dogs with pruritic and inflammatory skin conditions, such as atopic dogs. It is believed that they shift the availability of eicosanoid precursors toward the production of mediators that are less inflammatory. Because fatty acids are a component of the phospholipid portion of cell membranes, dietary intake will affect membrane composition. Dietary n-3 and n-6 fatty acids compete for the same metabolic enzymes in the body. Competition exists for chain elongation and desaturation of LA and ALA to 20-carbon eicosanoid precursors. Activation of membrane phospholipases initiates a metabolic cascade in which both n-3 and n-6 phospholipid fatty acids competitively react with enzymes and are incorporated into LTs, prostaglandins, and hydroxylated eicosatetraenoic acids. Physical or chemical trauma to the cell membrane causes n-6 fatty acids (primarily AA [20:4n-6]) to be converted into prostaglandins of the 2 series (prostaglandin E₂) and LTs of the 4 series (LTB₄). By contrast, the n-3 fatty acids are transformed into prostaglandins of the 3 series (prostaglandin E₃) and LTs of the 5 series (LTB₅), which are less proinflammatory than their corresponding n-6 fatty acid isomers. Consequently, newly synthesized LT₄ serves to inhibit LT₅-mediated neutrophil activation and thus diminish LT₅-mediated allergic or inflammatory conditions in skin and other tissues.

Clinical evidence for such an effect was reported in a study in which dogs with pruritic skin disease were provided diets supplemented with high amounts of n-3 long-chain fatty acids (660 mg/kg [300 mg/lb] of body weight/d) during a 6-week period. At the end of the study, dogs had significant improvement for pruritus as well as skin and coat character. It should be mentioned that the diets of those dogs were not otherwise controlled in that study, and most dogs consumed the majority of their calories from commercially available, dry, extruded-type diets.

**Effects of n-6 Fatty Acids**

An anti-inflammatory effect of n-6 fatty acids may also exist. It apparently would involve dietary GLA (18:3n-6), which is a precursor of DGLA (20:3n-6). Although GLA can also be further converted into AA, increased dietary amounts of GLA result in the accumulation of DGLA, which competes with AA for incorporation into cell membranes. Thus, when cells are stimulated to form eicosanoids, DGLA gives rise to mediators that are less inflammatory, compared with the inflammatory effects of those that arise from AA. However, conflicting results were found in a study conducted on dogs to evaluate the use of GLA-containing oil supplements in clinical settings.

**Dietary Supplementation of n-3 Fatty Acids for Skin Disorders**

Primary indications for dietary supplementation of fatty acids include pruritus associated with dietary hypersensitivity (such as flea bite dermatitis); atopic dermatitis; and disorders associated with abnormal fatty acid metabolism, including keratinization defects. In general, LA-containing supplements may be harmful for dogs with dry, flaky skin without concomitant inflammation. It must be remembered that each gram of oil will contain approximately 9 kcal and that 5 mL (1 teaspoon) of vegetable oil is approximately 4.6 g (approx 42 kcal). Switching to a diet with a higher fat content may also be useful for these dogs, but clinicians must be careful that they do not add too many calories to diets of small-breed dogs or dogs prone to obesity. When inflammation is a component of a skin disorder, n-3 fatty acid supplements or dietary modifications with n-3 fatty acids (especially eicosapentaenoic acid) are beneficial. As mentioned previously, most clinical studies that have attempted to evaluate the use of n-3 fatty acids for dogs with skin disorders have not evaluated the overall dietary fatty acid content. Nonetheless, 1 appropriately designed clinical study revealed that for dogs with pruritic skin disease, supplementing the diets with marine fish oil at a dosage of 1 g of fish oil/4.54 kg [1 g of fish oil/2.06 lb] of body weight for 6 weeks was an effective treatment. This dosage is currently recommended for a therapeutic effect and has a reasonable margin of safety.

**Interactions between Zinc, Fatty Acids, and Skin Health**

In addition to dietary fatty acids, zinc plays a vital role in regulating several aspects of cellular metabolism, many of which are associated with the maintenance of healthy skin and coat. Two of the most widely researched nutritional skin problems are those related to zinc and LA. Zinc is essential for the conversion of LA to AA through activation of the A-6 desaturase enzyme. Subsequently, AA can be incorporated into cell membranes and serve as substrate for prostaglandin or LT synthesis. Therefore, zinc is required for the use of fatty acids and is a participant in both the inflammatory and immune systems. As a cofactor for RNA and DNA polymerases, zinc is also important for rapidly dividing cells, which include those in the epidermis. Although
rare, common signs of zinc and EFA deficiencies are similar in that both are associated with sebaceous gland hypertrophy that leads to a greasy, dull coat. However, zinc deficiency typically results in a more profound seborrhea with distinctive keratinization (parakeratotic hyperkeratosis) that is evident during histologic examination.

Whether additional dietary zinc (in excess of minimum amounts) would be beneficial is a topic of interest with regard to skin health. In 1 study, investigators supplemented an existing diet with LA, zinc, and a combination of LA and zinc and assessed skin and coat quality in dogs. The total LA and zinc contents ingested were 12.75% metabolizable energy (approxi 15 g/1,000 kcal) and 100 mg/1,000 kcal, respectively. Dogs provided the supplemented diet containing the combination of LA and zinc had significant improvements in skin and coat condition. Specifically, dogs fed increased amounts of LA and zinc had less scaly skin, more luster of the coat, and a reduction in transepidermal water loss, compared with results for a control group fed a basal diet containing the currently recommended minimal amounts of LA and zinc (as recommended by the National Research Council). Skin of dogs fed diets supplemented with zinc or LA alone did not have improvements by use of these measures. Analysis of these data suggests that an interaction between zinc and LA may exist that results in substantial enhancement of the skin and coat of dogs. It was hypothesized that supplemental zinc and LA must be provided in combination in the diets of healthy dogs for improvements in skin condition to be evident.

A study was performed by our laboratory group to investigate effects of dietary fatty acids and zinc on skin and coat conditions of dogs. An analysis of the lipids in skin sebum contained in hair samples was conducted in that study. The study included samples obtained from 24 dogs (9 female Beagles and 15 Hound-crossbred male dogs) initially fed an extruded commercial diet containing 9% fat (on an as-is basis) for a 12-week acclimation period. For the subsequent 12 weeks, dogs were fed maintenance amounts of 1 of 3 experimental diets (diet A contained adequate amounts of EFAs [2.5% of energy in the diet from LA] and zinc [120 mg/kg of diet], whereas diets B and C contained higher but differing amounts of EFAs [diet B, 8.8% of energy in the diet from LA; diet C, 8.8% of energy in the diet from LA plus ALA] and higher amounts of zinc [diets B and C each contained 350 mg/kg (159 mg/lb) of diet]). Total dietary fat of all 3 diets was approximately 13% (on an as-is basis); the diets were isocaloric (3,800 kcal/kg [1,727 kcal/lb] of diet) and met standards established by the Association of American Feed Control Officials for all nutrients. A panel of evaluators was trained to evaluate skin and coat condition of dogs; evaluations were performed before, during, and after the feeding periods.

In that study, all 3 diets resulted in improvements in skin and coat scores beginning as early as 7 weeks after initiation of feeding, with the most dramatic differences detected for increased coat glossiness and softness. These improvements appeared to be attributable, at least in part, to the higher total dietary fat concentrations of the diets, compared with concentrations for the acclimation diet, rather than to differences in polyunsaturated fat types. Indeed, diet A contained higher amounts of saturated fat, compared with contents of diets B and C, whereas dietary total fat content was similar among all 3 diets, yet all coat scores were improved. Although zinc effects were not detected, that study was not designed to specifically address increased zinc content at a constant amount or type of fatty acid; thus, we did not expect to detect effects attributable to dietary zinc.

Of additional interest in that study were changes in the major lipid fractions from extracts of hair samples quantified after thin-layer chromatography and densitometry with external standardization. Significant increases in total cholesteryl ester concentrations were found in hair samples obtained from all 3 experimental diet groups at the end of the feeding period. Whether this lipid alteration was correlated with skin and coat improvements is unknown at this time because some lipid extracts of hair from individual dogs on specific sample days had to be pooled prior to analysis. Thus, additional studies are warranted. Nonetheless, it is of interest that preliminary data indicate an increase in lipid cholesteryl ester concentrations on the hair surface and improvements in skin and coat when diets with higher fat content are fed. Should a positive correlation exist between these 2 variables, lipid analysis of hair samples may provide a useful, noninvasive technique to quantify dietary effects on skin and coat. Consistent with this possibility is that another study also revealed an increased sebum cholesteryl ester fraction in dogs fed diets containing increased amounts of total fat. Furthermore, our laboratory group has reported that diets with increased amounts of total fat also will increase plasma cholesteryl ester concentrations in dogs. This finding also supports the subsequent increase in cholesteryl ester in surface lipids of hair that may then impart a major improvement in coat glossiness and softness.

Clinical Summary

Dietary supplementation or inclusion of both n-6 and n-3 fatty acids appears to have a beneficial effect on skin health of dogs. Reasons for this benefit include direct epidermal enrichment of EFAs, a possible sparing effect of ALA on LA in skin ceramide lipid fractions, and less water loss. It is also likely that a synergistic effect exists between greater-than-minimal dietary amounts of LA and zinc, with a beneficial effect on the coat of dogs.

Diets containing increased amounts of total dietary fat, rather than some specific combination of fatty acids, also appear to result in more desirable amounts of coat gloss and softness. This benefit may be related to increased amounts of cholesteryl ester deposited on the hair surface when high-fat diets are fed. We speculate that increased amounts of cholesteryl ester may be incorporated and subsequently detected on the follicle and sebum of hair shafts, thereby resulting in improvement of skin, coat sheen, and appearance of the coat of dogs, especially when high-fat diets are fed. Diets containing increased amounts of total fat result in increases in plasma cholesteryl ester concentrations that
may translate into increases in lipid on the hair. This
does not detract from the use of diets properly balanced
for n-6 and n-3 polyunsaturated fatty acids because the
combination of higher amounts of total dietary fat and
appropriate amounts of specific polyunsaturated fatty
acids contributes to optimized lipid nutrients for dogs.

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