Cats Require More Dietary Phenylalanine or Tyrosine for Melanin Deposition in Hair than for Maximal Growth

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ABSTRACT In 1986, the NRC recommended a dietary concentration of 4.0 g/kg of phenylalanine and 8.5 g/kg of total aromatic amino acids for growing kittens on the basis of maximal growth rate and nitrogen balance. Black hair-coated cats were given purified diets containing the following phenylalanine + tyrosine (Phe + Tyr) concentrations (g/kg diet): 4 + 2, 4 + 4, 4 + 6, 4 + 8, 10 + 0, 10 + 2, 10 + 4, 10 + 6, 10 + 8, 10 + 10, 24 + 0 for at least 6 mo. All other amino acids were present at about twice the requirements. Total melanin and the oxidation product of melanin, pyrrole-2,3,5-tricarboxylic acid (PTCA) were measured in hair. There was a significant linear relationship between the concentrations of tyrosine in plasma and PTCA in hair. The relationship between PTCA concentration in hair and Phe + Tyr in the diet had a point of inflection at ~16 g/kg Phe + Tyr. Cats fed diets with <16 g Phe + Tyr developed “red hair.” We confirmed the anecdotal reports that the black hair of cats can change from black to reddish brown. An aromatic amino acid concentration ≥18 g/kg is recommended for the prevention of visually discernible red hair in black-coated cats. Dietary concentrations >18 g total aromatic amino acids/kg diet promote a greater ratio of PTCA:total melanin in hair. We are unaware of a secondary nutrient requirement being so much greater than the requirement for growth. J. Nutr. 132: 2037–2042, 2002.

KEY WORDS: • melanin • eumelanin • tyrosine • phenylalanine • cats

The color of mammalian hair results mainly from the secretory products of the melanocytes. Organelles referred to as melanosomes within these specialized dendritic cells synthesize melanin, which is secreted into the surrounding keratinocytes where they become incorporated into the hair. Follicular melanocytes differ from those in the epidermis in that they synthesize larger melanosomes, are active only during anagen stages III–VI of hair growth, and are inactive during telegen (1). Two types of melanin are synthesized in follicular melanocytes: eumelanin, which is brown to black, and pheomelanin, which is reddish-brown (2). The pathways for the synthesis of these two types of melanin were presented by Morris et al. (3). The physiologic signals that regulate this switch include the α-melanocyte-stimulating hormone and the agouti protein (4). Dihydroxyphenylalanine (DOPA), 3 the hydroxylated product of tyrosine, is the precursor of both types of melanin. We have been unable to find any reference to the effect of dietary tyrosine (or phenylalanine) on the color of mammalian hair. However, the tendency for phenylketonuric human subjects to have fair hair has been commented upon from time to time since the first observations of Folling in 1934 (5).

Rogers and Morris (6) demonstrated that phenylalanine was an essential amino acid for growing kittens, but tyrosine was dispensable when the diet contained adequate Phe. These authors also demonstrated that the phenylalanine requirement for maximal growth was not >7.5 g/kg diet in the presence of 10 g tyrosine/kg diet. Anderson et al. (7), using Latin-square designs, showed that the phenylalanine requirement of growing kittens was not >5 g/kg diet in the presence of 5 g tyrosine/kg diet. Further refinements to the aromatic amino acid requirement of growing kittens were made by Williams et al. (8) who reported a total requirement of 7.5 g/kg diet, of which about half could be supplied by tyrosine. This latter study used a Latin-square design of 10-d periods and based the requirement on the minimal phenylalanine or phenylalanine plus tyrosine for maximal growth and nitrogen balance. The NRC (9) recommended a total amino acid requirement of 8.5 g/kg diet, with a minimum of 4.0 g phenylalanine/kg diet. The above values plus a slight overage for bioavailability were used by the Association of American Feed Control Officials (AAFCO) (10) for the Cat Food Nutrition Profile used by the pet food industry. AAFCO (10) recommended that diets for both kittens and adult cats should contain 8.8 g phenylalanine plus tyrosine/kg diet with a minimum of 4 g phenylalanine.

Subsequent longer-term studies (11) demonstrated that diets based on gelatin, containing amino acids in excess of the NRC (9) recommendations, resulted in the coat hair of black cats turning reddish-brown. The change in coat color was also produced when cats consumed diets based on isolated amino acids that included 12 g phenylalanine plus 4.5 g tyrosine/kg.
diet. These levels were greatly in excess of those recommended (9,10). However, when black cats consumed a diet that contained 24 g phenylalanine/kg diet, and no tyrosine, there was no change in hair color. These studies indicated that the recommended (9,10) levels of phenylalanine and tyrosine were inadequate to maintain black hair coat in cats.

The present study investigated the effects of a range of dietary levels of phenylalanine and tyrosine on coat color in black cats. Studies were conducted over periods of 6–9 mo to assess the level of dietary phenylalanine and tyrosine required to maintain black hair color.

**MATERIALS AND METHODS**

**Animals.** Specific pathogen-free domestic short-hair cats and kittens (n = 53) with black hair coats from the Feline Nutrition and Pet Care Center, University of California at Davis were used. At all times, cats and kittens consumed a purified diet and water ad libitum. The experimental protocol was approved by the Animal Use and Care Administrative Committee of University of California, Davis and conducted in accordance with the NIH guidelines (12) and the Animal Welfare Act. Cats were housed either singly in 60 × 60 × 60 cm stainless steel metabolic cages or in pairs in 1.4 m² cages. Room temperature was maintained at 21 ± 2°C with a minimum light:dark cycle of 14 h/10 h.

**Diets.** Eleven purified diets containing the following proportions of phenylalanine and tyrosine, respectively (g/kg diet) were prepared: 4 + 2; 4 + 4; 4 + 6; 4 + 8; 10 + 0; 10 + 2; 10 + 4; 10 + 6; 10 + 8. Crystalline amino acids (Ajinomoto USA, Teaneck, NJ) supplied the nitrogen in all diets, and the essential amino acids with the exception of phenylalanine and tyrosine, were supplied at 1.6–2 times the NRC (9) recommendations. The crude protein (N × 6.25) was held constant at 280 g/kg diet by using an essential (EAA) and a dispensable (DAA) amino acid mixture. The amount of the DAA mixture was adjusted for the nitrogen supplied as phenylalanine and tyrosine. The EAA mixture contained (g/kg diet): L-Arg HCl, 20; L-His HCl H₂O, 6; L-Ile, 10; L-Leu, 24; L-Lys HCl, 16; L-Met, 8; L-Cys, 7; L-Thr, 14; L-Trp, 3; L-Val, 12. The DAA mixture contained (g/kg): L-Ala, 175; Gly, 175; L-Gln, 175; L-Asp, 150; L-Pro, 150.

The constant ingredients in the diets were as follows (g/kg diet): chicken fat (Foster Farms, Livingston, CA) 240; starch (Melojel, Santa Clara, CA) 275.5; sucrose, 100; cellulose, 20; mineral mixture 50 (8); vitamin mixture 5 (8); National Food Starch and Chemical, Bridgewater, NJ) 2.5. The diets were blended in a 40-L food mixer, maintained 24 g phenylalanine/kg diet, and no tyrosine, there was no change in hair color. These studies indicated that the recommended (9,10) levels of phenylalanine and tyrosine required to maintain black hair color.

### Experimental design

An insufficient number of black cats were available at one time to supply all cats needed for the 11 dietary treatments. Therefore, cats were allocated to one of four diet groups after they were accustomed to a purified diet and were gaining body weight (Table 1). The ages of the cats in group 1 ranged from 3 to 8 mo, those in groups 2 and 3, 2–3 mo and cats in group 4, 2–4 mo. The groups are described below.

**Group 1.** Cats in this group had initial body weights ranging from 2.1 to 4.1 kg; they were older than those in groups 2–4 and included 13 females and 5 males. Treatments commenced on March 6, 1999 and continued for 269 d. The cats were allocated as follows to the dietary treatments: Phe + Tyr (4 + 2 females); 4 + 4 (2 females); 4 + 6 (2 females); 4 + 8 (1 male and 1 female); 10 + 0 (2 females); 10 + 2 (4 males); 10 + 4 (2 females) and 10 + 6 (2 females).

**Group 2.** The 7 males and 5 females in this group had initial body weights that ranged from 0.9 to 1.7 kg. Treatments commenced on April 26, 1999 and continued for 227 d. The cats were allocated to the dietary treatments as follows: Phe + Tyr: 4 + 2 (1 male and 1 female); 4 + 4 (2 males); 4 + 6 (1 female); 4 + 8 (1 female); 10 + 0 (2 males); 10 + 2 (1 male and 1 female) and 10 + 6 (1 female).

**Group 3.** The 5 males and 5 females in this group had initial body weights that ranged from 0.9 to 1.2 kg. Treatments commenced on August 20, 1999 and continued for 210 d. The cats were allocated to the following dietary treatments Phe + Tyr: 4 + 2 (four males); 4 + 6 (2 males); 4 + 8 (2 males); 10 + 2 (2 males) and 10 + 4 (2 males).

**Group 4.** The 5 females and 7 males in this group had initial body weights of 0.8 to 1.5 kg and were allocated to the three dietary treatments Phe + Tyr: 10 + 8 (2 males and 2 females); 10 + 10 (3 males and 1 female) and 24 + 0 (2 males and 2 females). Treatments commenced May 5, 2000 and continued for 191 d.

Food intakes were measured daily and body weights were recorded weekly. Blood samples (3 mL) were drawn from the jugular veins of unanesthetized cats into heparinized syringes every 1–2 mo. Plasma was frozen at −80°C until analyzed for free amino acids. At the beginning of each experiment, a rectangular area approximately 7 × 5 cm on the lateral abdomen of each cat was shaved. New hair growth within this area was evaluated for the presence of red hairs and then shaved at the time of each blood sampling and used for the analysis of melanin or pyrrole-2,3,5-tricarboxylic acid (PTCA).

**Analytical methods.** Plasma amino acid concentrations were determined on a Model 7300 Beckman Amino Acid Analyzer (0.4 cm × 10 cm column packed with spherical cation exchange resin, Beckman Instruments, Palo Alto, CA). Before analysis, plasma was mixed with an equal volume of 0.28 mol/L sulfoxylic acid. The resulting precipitate was removed by centrifugation at 16,000 g. Lithium hydroxide was added to an aliquot of the supernatant to adjust the pH to 2.2 and the equivalent of 20 μL of plasma was injected onto the column of the analyzer.

Total melanin was determined according to the method of Ozeki et al. (2) by dissolving 5 mg hair in 3 mL of Soluene-350 (Packard Instrument, Meriden, CT). Once the hair was completely solubilized, the optical density was determined in a Beckman Recording Quartz Spectrophotometer (Beckman Instruments, Fullerton, CA) at wavelengths of 500 and 650 nm; the latter wavelength provides an index of the proportion of phaeomelanin in the hair. A standard curve for total melanin was constructed using Sepia melanin standards (Sigma

**TABLE 1**

**Grouping of cats and number according to treatments**

<table>
<thead>
<tr>
<th>Treatment (phenylalanine + tyrosine g/kg diet)</th>
<th>Group 1</th>
<th>Cats, n</th>
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<tbody>
<tr>
<td>4 + 2</td>
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<tr>
<td>4 + 4</td>
<td>4</td>
<td>3</td>
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<tr>
<td>4 + 6</td>
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<td>4 + 8</td>
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<tr>
<td>10 + 0</td>
<td>1</td>
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<td>10 + 2</td>
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<tr>
<td>10 + 4</td>
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<td>10 + 6</td>
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<td>10 + 8</td>
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<td>10 + 10</td>
<td>4</td>
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</tr>
<tr>
<td>24 + 0</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

1 Refers to the group of cats assigned to the treatment.
Chemical, St. Louis, MO) dissolved in Soluene-350. The CV of the total melanin assay was 5.6% for black cat hair. Analyses were done in triplicate.

The measurement of PTCA concentration in hair was based on a modification of the peroxide oxidation method of Ito and Wakamatsu (13). Briefly, 10 mg hair was added to a mixture of 100 μL deionized water, 840 μL K₂CO₃ (1 mol/L) and 60 μL H₂O₂ (30%) in a 20 × 125 mm screw-cap Pyrex culture tube (Corning Glass Works, Corning, NY). The tubes and contents were placed in a 90°C water bath until the hair was digested. After the sample had cooled to room temperature, 20 μL Na₂SO₄ (10%) and 500 μL HCl (6 mol/L) were added to the digest. The samples were twice extracted with 7 mL diethyl ether, and extracts were pooled and evaporated under nitrogen. The residue was suspended in 200 μL deionized water and 20 μL was injected onto a 4.6 mm × 250 mm Xterra MS C₁₈ 5 μm HPLC column (Waters, Milford, MA) heated to 55°C with a phosphate buffered mobile phase at pH 2.1 containing 2% (v/v) methyl alcohol. The CV of the working standard of PTCA was 1.1%, and for digested and ether-extracted hair from a control cat, was 3.5%.

In addition to the objective measurements of melanin and PTCA, the overall hair color of the cats was subjectively assessed by a visual scoring system using a scale of 0 to 6 in which 0 = black, 1 = light brown, 2 = brownish black, 3 = medium brown, 4 = light brown, 5 = gray-light brown, 6 = gray. Statistical analyses. Data were analyzed by one-way ANOVA and the post-hoc Tukey-Kramer multiple comparisons test. Differences were considered significant at < 0.05.

RESULTS

The PTCA concentrations in hair of cats in dietary treatments 4 + 2 to 10 + 2 in relation to the time they received the diet are shown in Figure 1. The decline in concentration of PTCA indicated that there was a decrease in eumelanin concentration in hair. In contrast, in Figure 2, the mean PTCA concentrations in the hair of the cats from the 10 + 6 to the 24 + 0 g/kg dietary treatments followed a positive trend with time, indicating increasing concentrations of eumelanin in hair. In this figure, the values for the cats in the 10 + 6 g/kg group remained almost constant and the concentrations for the 10 + 6 g/kg treatments were negatively related with the time they received the diet. These observations indicate that a concentration of 10 + 6 g/kg Phe + Tyr is inadequate to maintain black hair. This was supported by the visual assessment of overall coat color (data not shown).

As would be anticipated, there was a general positive relationship between the concentration of Phe + Tyr in the diet and the concentration of tyrosine in plasma (Fig. 3). However, it was not until the sum of Phe + Tyr was ≥18 g/kg diet that a marked elevation of the concentration of tyrosine in plasma occurred. Values are also presented for redness score of the new hair grown in the clipped area in relation to plasma tyrosine concentration. The redness score for cats fed ≥18 g total aromatic amino acids/kg diet was 0, indicating the absence of red hairs. Below this dietary concentration, cats had increasing numbers of red hairs. The sum of the dietary concentration of Phe + Tyr was also positively related to the PTCA concentration in hair, but the relationship exhibited a discontinuity at ~16 g/kg. In Figure 4, the relationship of dietary concentration of Phe + Tyr from 6 to 16 g/kg diet on PTCA concentration in hair had a lower slope, (and a lower r² value), than for dietary concentrations of 16–24 g/kg. The point of intersection of the two linear phases occurred between 16 and 18 g Phe + Tyr/kg diet.

When the values for PTCA concentration in hair for all treatment groups were regressed on the concentrations of tyrosine in plasma (Fig. 5), there was a significant positive relationship (r² = 0.87). This relationship indicates that plasma concentration of tyrosine was the prime determinant of the concentration of PTCA in hair and agrees with the relationship of the subjective visual assessment of red hairs in the newly grown hair in the shaved patches and concentration of plasma tyrosine presented in Figure 3.

The relationship between the concentrations of PTCA and total melanin in hair for treatments of 10–24 g Phe + Tyr/kg diet is presented (Fig. 6). At concentrations of 10–16 g/kg diet, the ratio was essentially similar, but at a concentration
In addition to the loss of color, hair growth of cats fed dietary Phe/Tyr concentrations of 4/2 and 4/4 g/kg was also compromised. The first sign observed was alopecia surrounding the mouth and eyes, which spread over the entire facial area, then to the flanks and limbs. Whiskers became brittle and broke off giving the appearance that the cats had been clipped. The hair on the body became rough, dry, gray and thin, particularly on the flanks and limbs. Because hypothyroidism is associated with similar hair changes as those observed in these cats, and as tyrosine is a precursor of the thyroid hormones, a serum sample was taken from 4, 2, 7, 4, 10, and 10 g/kg diet, respectively, for measurement of thyroid status. Free and total thyroxine (T4), free and total triiodothyronine (T3), and thyroid stimulating hormone (TSH) were measured by the Animal Health Diagnostic Laboratory, Michigan State University, East Lansing. All of the values lay within the normal range for cats. No significant differences between groups were found except for free T3. Free T3 values of cats receiving the Phe/Tyr 4/6 g/kg diet were 3.7 ± 0.4 pmol/L, (n = 7) and differed (P < 0.01) from that of cats receiving the Phe/Tyr 10/0 diet [(1.8 ± 0.3 pmol/L, (n = 4)]. The reason for this difference is not known as these two groups were not different in any other way.
groups received the same sum of phenylalanine + tyrosine in the diet. Hair growth was normal when the cats consumed dietary Phe + Tyr concentrations of 4 + 6 and 4 + 8 g/kg diet, but the new growth was brown in color, not black, which was reflected in the PTCA concentrations that remained below 50 μmol/L. The greater Phe + Tyr concentrations also resulted in normalization of the whiskers. Neither feed intake (P = 0.47) nor live weight gain (P = 0.39) was compromised in cats given the Phe + Tyr 4 + 2 and 4 + 4 g/kg diets compared with cats given the other treatments.

Because all amino acids other than phenylalanine and tyrosine were present at 1.6–2 times the level recommended by the NRC (8), the low dietary Phe + Tyr levels were limiting hair growth. Plasma tyrosine levels were as low as 4.4 ± 0.8 μmol/L in cats given the Phe + Tyr 4 + 2 g/kg diet. This is very low compared with cats in our colony given a 20% higher level of the diet. Hair growth was normal when the cats consumed 2 g/kg diet to the 10 g/kg diet developed a neurological condition involving the posterior limbs and tail. On a slow walk, the cats had extended hind legs, resulting in an uncoordinated gait. The tail was held vertically, bending upward and forward over the back. On a fast walk, affected cats hopped on their hind legs. The most severely affected cat was hyperactive; it hypersalivated and emitted frequent vocalizations. Three affected cats were subjected to neurological examination. Conduction velocities of the peripheral nerves of the hind limbs were measured using evoked potentials. Two cats had ~50% reductions in sensory nerve conduction velocity, but motor nerve conduction velocities were within the normal range. Histologic examination of nerve biopsies showed marked Wallerian degeneration of axons with secondary myelin collapse. A separate report will describe the neurological findings.

The most severely affected cat was transferred from the 10 + 2 g/kg diet to the 10 + 6 g/kg diet and within 1 mo, there was a marked improvement in hind limb coordination, vocalization was reduced and the hyperactivity disappeared. No adverse clinical signs were observed in cats given diets with phenylalanine + tyrosine concentrations ≥10 + 6 g/kg.

**DISCUSSION**

This study demonstrated that black cats require higher dietary Phe + Tyr concentrations for the maintenance of coat color than the values given by either NRC (9) or AAFCO (10). Because black hair color is determined by the proportion of the brown-pigment eumelanin compared with the reddish brown pigment pheomelanin, it appears that genetic variation in the melanocyte to control tyrosine hydroxylase, PH and tyrosinase activity (19). PH and tyrosinase are key enzymes that control the biosynthesis of melanin. PH is encoded by the Tyr gene and is responsible for the conversion of L-tyrosine to L-DOPA. Tyrosinase, encoded by the Phe gene, is responsible for the conversion of L-DOPA to dopaquinone, which inhibits glutathione reductase and γ-glutamyl transpeptidase (enzymes required for pheomelanogenesis). L-Tyrosine is not only a precursor of melanin but also increases the activity of tyrosinase, thereby enhancing melanin synthesis (15).

Using cultured melanocytes, it was shown (16) that the pigmentation pattern changed with varying concentrations of cysteine and tyrosine in the media. High tyrosine and low cysteine concentrations favored eumelanogenesis. Because all of the diets we used contained the same concentrations of Met and Cys, the Cys pool in the plasma for the melanocyte should have been adequate, and similar in cats across all treatments. However, the concentration of tyrosine in plasma varied with the dietary Phe + Tyr concentration (Fig. 3) and presumably the tyrosine pool available to the melanocytes reflected these changes. At low concentrations of dietary Phe + Tyr, the cysteine to tyrosine ratio in the pool would have favored pheomelanin synthesis and a greater proportion of “red hair.” With <16 g/kg of Phe + Tyr, the concentration of tyrosine in the plasma increased only slowly with increasing Phe + Tyr, whereas above ~16 g Phe + Tyr/kg diet, the rate of increase in tyrosine in plasma was accelerated as illustrated in Figure 3. Coincidental with this increase in plasma tyrosine, the incidence of visually apparent “red hair” disappeared (Fig. 3). In addition, >16 g Phe + Tyr/kg diet led to a marked increase in the concentration of PTCA (an index of eumelanin) in hair (Fig. 4). This conclusion is further supported by the significant positive relationship between the concentration of plasma tyrosine and PTCA in hair (Fig. 5). Hair growth was also compromised by low dietary concentrations of Phe + Tyr. Although black cat hair contains 184 ± 2.4 μmol Phe and 247 ± 7.2 μmol Tyr/g lipid-free dry matter (17), the loss from the body through hair is trivial (~2.5 mg Phe + Tyr/kg body weight · d).

Tyrosine used for the synthesis of melanin may originate from plasma tyrosine or from phenylalanine after hydroxylation with phenylalanine hydroxylase (PH). As a measure of “potentially available tyrosine” to the follicular melanogenesis, we used the sum of dietary phenylalanine and tyrosine. However, studies using nonfeline melanocyte cultures indicated that phenylalanine may be a more efficiently used source of tyrosine for the follicular melanocyte than dietary tyrosine. Epidermal melanocytes express mRNA for PH in association with considerable enzyme activity. Cultured human epidermal melanocytes in the presence of L-phenylalanine produce ~40% more melanin than an equivalent concentration of L-tyrosine (18). The transport of extracellular L-phenylalanine and its intracellular metabolism to L-tyrosine by PH are coupled with calcium transport, whereas L-tyrosine uptake by melanocytes is calcium independent. The cofactor for PH, 6(R)-l-erythro 5,6,7,8, tetrahydrobiopterin, is produced de novo and is recycled and regulated in melanocytes and keratinocytes to control tyrosine hydroxylase, PH and tyrosinase activity (19).

The considerably greater dietary intake of Phe + Tyr required to maintain black hair in cats than for maximal growth is consistent with the apparent K_m values reported for reactions involving tyrosine. The K_m of the acyl synthetase is 4 × 10^{-5} mol/L (20), whereas the catabolic enzyme (tyrosine aminotransferase) is ~375 times greater (1.5 × 10^{-3} mol/L) (21). Tyrosinase is the key enzyme that controls the biosynthesis of melanin (22). A range of apparent K_m values for tyrosinase from murine melanomas has been reported. In one study, the apparent K_m values for tyrosine and DOPA were 7 × 10^{-4} and 6 × 10^{-3} mol/L, respectively (23), and in a subsequent study, apparent K_m values of two isoenzymes of
tyrosine for tyrosine were 1.2 × 10⁻⁴ and 2.3 × 10⁻⁴ mol/L (24). \( K_m \) values reported for tyrosine isolated from cephalopod ink were higher (1.7 × 10⁻⁴ and 10 × 10⁻³ mol/L, respectively) for L-tyrosine and L-DOPA (25). The mammalian \( K_m \) value of tyrosine for tyrosine indicates that the concentration of tyrosine for melanin synthesis would have to be ~3 to 17 times higher than that required for growth.

Our study demonstrating that melanin in cat hair was positively related to the concentration of dietary tyrosine with a constant (10g/kg) phenylalanine concentration, does not support the conclusions of Schallreuter (19) who asserted that "the active transport of l-phenylalanine and its autocrine turnover to i-tyrosine via FH in the cytosol of the epidermal human melanocyte provides the majority of the l-tyrosine pool for melanogenesis."

The observation that the clinical signs of hyperactivity and ataxia resolved or were reduced after the most severely affected cats were given the 10 + 6 g/kg diet suggests the involvement of tyrosine in catecholamine production rather than structural nerve degeneration. In catecholamine synthesis, the conversion of tyrosine to DOPA is catalyzed by tyrosine hydroxylase, which is the rate-limiting enzyme of the pathway. Isolates of the enzyme from the preoptic region and hypothalamus of rats both gave apparent \( K_m \) values of 8 × 10⁻⁵ mol/L for tyrosine (26,27), which is considerably lower than the \( K_m \) for tyrosine, but about twice the \( K_m \) of the acyl synthetase. Other factors in addition to the \( K_m \) value, such as transport, may have a role in determining catecholamine synthesis. Tyrosine deficiency is manifested in multiorgan systems, including a reduction in hair growth and follicle density, hair color and peripheral sensory neuropathy, which is probably related to the origin in the vertebrate embryo of the skin melanocytes and hair bulbs in the neural crest (28).

Red coat has been described in dogs and cats given certain commercial and therapeutic foods. However, reports of its occurrence have been mainly anecdotal, such that it has generally been considered to be a myth or "an old wives tale" (29). The present study indicates that eumelanin production in cats is compromised if the sum of readily available dietary Phe + Tyr is <16 g/kg diet. We recommend that the dietary phenylalanine-tyrosine requirement be increased to at least 366. Phenylalanine-tyrosine requirement for growth of the young kitten. J. Nutr. 109: 718-723.


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