The feline iodine requirement is lower than the 2006 NRC recommended allowance*†‡

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Introduction

Iodine (I) is a major constituent of the thyroid hormones thyroxine (T₄) and 3,3′,5′-triiodothyronine (T₃) representing 65% and 59% of their respective weights. Thyroid hormone plays a major role in cell differentiation, growth and development in growing animals, and in the regulation of metabolic rate in adults. Many key biochemical reactions such as protein synthesis and enzyme activity are regulated by thyroid hormones and major affected organs include brain, heart, muscle, pituitary and kidney (Dietary Reference Intakes, 2001).

Currently, there is a discrepancy between AAFCO and NRC with regard to the I requirement of adult cats. The National Research Council (2006) for cats recently proposed that the nutrient allowance for I in adult cats is 1.4 mg I/kg diet. This recommendation is four times higher than the current AAFCO (2008) minimum recommendation (0.35 mg I/kg diet) and is not in close agreement with the I requirement of other species. The new NRC I

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Summary

The purpose of this study was to determine the iodine (I) requirement in adult cats. Forty-two healthy euthyroid cats (1.6–13.6 years old) were utilized in a randomized complete block design. Cats were fed a dry basal diet (0.23 mg/kg I) for a minimum of 1 month (pre-test) then switched to a different basal diet supplemented with seven levels of KI for 1 year (experimental period). Analysed I concentrations were 0.17, 0.23, 0.47, 1.1, 3.1, 6.9 and 8.8 mg I/kg diet [dry matter (DM) basis] and used to construct a response curve. Response variables included I concentrations in serum, urine and faeces, urinary I:creatinine ratio, I balance, technetium⁹⁹m pertechnetate (Tc⁹⁹m) thyroid:salivary ratio, complete blood count and serum chemistries as well as serum thyroid hormone profiles. No significant changes in food intake, weight gain or clinical signs were noted. Serum I, daily urinary I, daily faecal I and urinary I:creatinine ratio were linear functions of iodine intake. An estimate of the I requirement (i.e. breakpoint) was determined from regression of Tc⁹⁹m thyroid:salivary ratio (scintigraphy) on I intake at 12 months [0.46 mg I/kg diet (DM basis) as well as 9 months I balance (0.44 mg I/kg diet (DM)]. The I requirement estimate determined in our study at 12 months for adult cats (0.46 mg I/kg) was higher than current Association of American Feed Control Officials (AAFCO) recommendations (e.g. 0.35 mg I/kg), but was lower than the 2006 National Research Council (NRC) I recommended allowance (e.g. 1.4 mg I/kg).
recommended allowances for the cat were based on three studies (Scott et al., 1961; Smith, 1996; Ranz et al., 2002) all of which failed to meet key criteria necessary for defining nutrient requirements. The Scott et al. (1961) study was never intended to be used as a requirement study; the diet used was an all meat diet (beef or sheep hearts) deficient in Ca, vitamin A and I and an imbalanced Ca:P ratio. Thus, the diet employed was not a nutritionally complete or balanced diet. Ideally, the diet used in defining nutrient requirements varies only in the nutrient in question and would meet or exceed NRC recommendations for all other nutrients. It is critical that the diet be nutritionally balanced so as to prevent negative interactions that could increase the requirement estimate for the nutrient being evaluated. The Smith (1996) study used percent I125 uptake as their criteria for defining I deficiencies and/or optimal I intakes. While use of radiolabelled I is considered a sensitive measure of thyroid function, in the Smith study, a subjective interpretation of their kinetic data was used to predict deficiency and adequacy. Key parameters (e.g. urinary I, faecal I or I balance) were not assessed and all other measurements from the Smith study (e.g. thyroid hormone profiles, thyroid histology, absence of clinical signs) suggested euthyroid state. Thus, no corroborating evidence was available to substantiate their interpretation of the thyroid kinetics data. The Ranz et al. (2002) study likewise had limitations which made it inappropriate for estimating nutrient requirements. Firstly, the study duration was too short to allow for homeostatic adaptation (e.g. 7 days only per dietary I treatment evaluated). Numerous studies have shown that for some nutrients, it can take several months for homeostasis to occur and only a 7-day depletion period was implemented in this study. When balance studies are used to estimate a requirement, the requirement is defined as the intake at which zero balance is attained. Their estimate of 100 µg I/day minimum intake needed to maintain positive I balance in cats is widely cited, but this estimate was derived based on measurements taken at high I intake and extrapolated back to zero intake as opposed to an experimentally derived estimate determined at low I intakes. Furthermore, the basal diet used in this study was 3.5 mg I/kg diet DM, [10-fold higher than current AAFECO (2008) minimum I recommendations for the cat; dietary I ranged from approximately 3.5–20 mg I/kg diet (DM)]. In people, 3.5 mg I/kg diet is considered a safe upper limit, thus the ranges of I evaluated in this study would be more appropriate for defining lowest observable adverse effect level (LOAEL) and no observable adverse effect level (NOAEL) as opposed to defining minimum requirements. The previous National Research Council (1986) for the cat estimated the I requirement for felines at 0.35 mg/kg diet based on data from other species and did not cite the Scott et al. (1961) reference.

It is important to compare nutrient requirements or recommendations between other monogastric species, because numerous nutrients (e.g. amino acids, trace minerals and vitamins) show remarkable similarity. The National Research Council (2006) minimum requirement for I in dogs, poultry (National Research Council, 1994), swine (National Research Council, 1998) and rats (National Research Council, 1995), is 0.70, 0.35, 0.14, 0.15 mg I/kg diet respectively. In humans, the recommended dietary allowance (RDA) for I (Dietary Reference Intakes, 2001) is 150 µg/day which on a metabolic equivalent basis equates to 0.51 mg I/kg diet for the cat (for calculation, see legend for Fig. 1). Thus, the 1.4 mg I/kg diet National Research Council (2006) recommended allowance for the adult cat is clearly higher than estimates for other species, suggesting that this esti-

![Thyroid scan ratio regressed on iodine intake (adult cat-wk 20)](image)

**Fig. 1** Regression of thyroid:salivary (T:S) ratio on iodine (I) intake (µmol/day) at week 20. A breakpoint was determined using a model involving two linear splines with no plateau. Each point (♦) represents an average of six cats. The x and y coordinates for the inflexion point determined for T:S ratio were 0.18 and 1.2 µmol/day respectively. The slope for T:S ratio above the inflexion point was 0.138 and below the inflexion point was 0.0008 (R² = 0.72). The human I dietary recommended intake of 150 µg/day equates to 0.51 mg I/kg diet metabolic bodyweight equivalent for the cat. Calculations are based on the following: 70 kg0.67 = 17.2; 150 µg I/17.2 kg BW0.67 = 8.72 µg I/kg BW0.67. Multiply the cat’s metabolic equivalent bodyweight by the factor derived from the human requirement: (5 kg0.67 = 2.94, 8.72 x 2.94 = 25.6 µg I daily I recommended intake. Assume typical cat daily intake = 50.2 g (derived from our study); 25.6 µg I/50.2 g = 0.51 µg/g or mg I/kg diet. BW, body weight.
mate should be revisited. Given the importance of I as a nutrient and the discrepancy that exists between NRC and AAFCO, it is important to quantify the minimum requirement for I in cats.

Materials and methods

Animals and study design

Experimental protocols were carried out in accordance with Institutional Animal Care and Use Committee guidelines. Cats were housed in a temperature-controlled environment (heat and air conditioning) and natural light was supplemented with full spectrum artificial light from 6:00 to 20:00 hours daily. The cats were individually housed during the evening and night-time hours and were provided an opportunity for going out of their enclosure enrichment with other cats and their caregivers most days of the week. Cat toys were provided in their enclosure and in the community animal room. Food was provided in their enclosure and water was provided ad libitum.

Forty-two adult cats (14 neutered males and 28 spayed females) ranging in age from 1.6–13.6 years (mean = 8.1 years) were utilized in a randomized complete block design. Cats were assigned to treatments (n = 7 treatments; 6 cats/treatment) and three groups (14 cats/block) based on the following blocking criteria: age, time on pre-test, weight and gender (in order of increasing to decreasing priority). Cats were fed a low I dry basal diet (0.23 mg/kg I) for a minimum of 4 to a maximum of 7 weeks (pre-test). Cats were then assigned to experimental diets (a different basal diet (0.17 mg I/kg diet) supplemented with seven levels of potassium iodide (KI) for 1 year (experimental period). The water at our facility was analysed to contain 0.005–0.001 mg/l I. Response variables included I concentrations in serum, urine and faeces, urinary I:creatinine ratio, Tc99m thyroid:salivary ratio (T:S), complete blood count (CBC) and serum chemistries as well as serum thyroid hormone profiles.

Diets

A nutritionally-balanced diet (Table 1) consisting primarily of corn gluten meal and corn was formulated to provide 34% crude protein, 20% fat, 4.2 kcal ME/g and 0.17 mg I/kg diet (DM basis). This same basal diet was used for all seven treatments, with the only dietary change being the substitution of KI for an equivalent weight of salt.

| Moisture (g/kg) | 36.0 |
| Protein (g/kg) | 339.0 |
| Fat (g/kg) | 181.0 |
| NFE (g/kg) | 409.0 |
| Ash (g/kg) | 50.0 |
| Fibre (g/kg) | 21.0 |
| Iodine (mg/kg) | 0.17 |
| Selenium (mg/kg) | 0.61 |
| Isoflavone (mg/kg) | 30.5 |

Ingredient list: corn gluten meal, corn, animal fat, egg, soybean mill run, meat protein isolate (pork), dicalcium phosphate, natural flavour, calcium carbonate, potassium chloride, lysine, choline chloride, methionine, non-iodized salt, yeast, Vitamin E oil, calcium sulphate, vitamin mixture†, potassium citrate, taurine, iodine and selenium-free mineral mixture‡, tryptophan.

| DM, dry matter; NFE, nitrogen free extract. |
| *Analysed nutrient analysis (DM basis). |
| †Vitamin mix delivers the following concentrations per 1 kg diet: vitamin A, 18 288 IU provided as retinyl acetate, vitamin D, 1078 IU provided as cholecalciferol, vitamin E, 119 IU provided as α-alpha tocopherol acetate, niacin, 151 mg; thiamin, 44 mg; d-pantothenic acid, 15 mg; pyridoxine, 8 mg; riboflavin, 10 mg; folic acid, 2.5 mg; biotin, 0.2 mg; and cyanocobalamin, 0.1 mg. |
| ‡Mineral mix delivers the following concentrations per 1 kg diet: FeSO₄·7H₂O, 87 mg Fe; ZnO, 150 mg Zn; MnO, 9 mg Mn; and CuSO₄·5H₂O, 12 mg Cu. |

The salt was split into three portions (treatments 2–4) or into two portions (treatments 5–7). The KI was added to the first portion of salt at its specified amount, but added to the salt in a ratio of approximately 10 parts KI and 90 parts salt. After thorough mixing, this first mixture was then added to the second portion of salt and homogeneously mixed. For treatments 2–4, this second mixture was then mixed with the third portion of salt and again thoroughly mixed. Analysed I concentrations at study start were 0.17, 0.23, 0.47, 1.1, 3.1, 8.8 and 9.2 mg I/kg diet (DM basis; Table 1—7, respectively, as described in Table 2). Two lots of each treatment were made; each lot was fed for approximately 24 weeks. Average analysed I concentrations measured during the 7-day balance period were 0.15, 0.24, 0.46, 1.1, 3.1, 8.2 and 9.2 mg I/kg diet (DM basis; Tables 3–5).

Sample analyses

Iodine analyses

Iodine analyses of food, serum, faeces and urine were performed using epiboron instrumental neutron activation analyses (EINAA) at the University of Missouri-Columbia Research Reactor Center.
In humans, normal urinary I reference ranges exceed 0.05 l/g creatinine (e.g. equates to 0.13 µmol/day for the cat or 0.04 µmol I/kg BW0.67) is adequate (Delange and Ermans, 1991).

§§Thyroidal uptake of 99mTcO4− was measured at Kansas State University. Thyroid:salivary (T:S) ratio was calculated as described by Henrikson et al. (2005). T:S ratio >1.66 is a positive test for hyperthyroid disease.

Mean values not bearing same superscript differ (p < 0.05).

Table 2: Response of adult cats to varying iodine (I) intakes (6 months)*

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Diet I ± 5D (mg/kg)</th>
<th>Food intake (g/day)</th>
<th>Daily I intake (µmol/day)</th>
<th>Serum Ia,b</th>
<th>Urine Ic,§,**</th>
<th>Urine I:cr,††</th>
<th>24 h Urine I:*** (µmol/day)</th>
<th>24 h Urine I:*** (% of I intake)</th>
<th>Tc99m scan†††§§</th>
<th>T:S ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.17 ± 0.02</td>
<td>46.8</td>
<td>0.06a</td>
<td>0.24a</td>
<td>1.10a</td>
<td>0.47a</td>
<td>0.03a</td>
<td>45.0a</td>
<td>3.41b</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.23 ± 0.01</td>
<td>52.9</td>
<td>0.10a</td>
<td>0.24a</td>
<td>1.26a</td>
<td>0.47a</td>
<td>0.04a</td>
<td>45.1a</td>
<td>3.01b</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.47 ± 0.01</td>
<td>46.8</td>
<td>0.17ab</td>
<td>0.32a</td>
<td>3.23a</td>
<td>1.42a</td>
<td>0.12a</td>
<td>66.4ab</td>
<td>1.62a</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.11 ± 0.12</td>
<td>54.2</td>
<td>0.47b</td>
<td>0.55a</td>
<td>7.41b</td>
<td>3.07b</td>
<td>0.33b</td>
<td>68.8b</td>
<td>1.18b</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>3.11 ± 0.02</td>
<td>52.5</td>
<td>1.29c</td>
<td>1.34b</td>
<td>19.46c</td>
<td>8.90b</td>
<td>0.79b</td>
<td>61.0b</td>
<td>1.03a</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6.86 ± 0.21</td>
<td>48.9</td>
<td>2.64d</td>
<td>3.07c</td>
<td>50.51d</td>
<td>21.59d</td>
<td>1.88d</td>
<td>71.0d</td>
<td>0.98d</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>8.83 ± 0.22</td>
<td>49.7</td>
<td>3.46a</td>
<td>3.63c</td>
<td>68.09c</td>
<td>29.31d</td>
<td>2.63d</td>
<td>75.9c</td>
<td>0.94a</td>
<td></td>
</tr>
<tr>
<td>Pooled SEM</td>
<td>4.2</td>
<td>0.10</td>
<td>0.24</td>
<td>1.34</td>
<td>1.02</td>
<td>1.14</td>
<td>7.9</td>
<td>0.26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

†Linear component significant (p < 0.05).
§§Quadratic component significant (p < 0.05).

*Data represent mean values of six cats at week 24 of experimental period; five cats for treatments 2–4; average age = 8.1 years. All cats were fed a pre-test diet containing 0.23 mg I/kg diet for a minimum of 4 week during the pre-test period.

††Iodine added as KI. Concentrations shown are analysed values (DM basis).

I, iodine; KI, potassium iodide; DM, dry matter.

Table 3: 7-day iodine balance (9 months)*

| Treatment | Diet I ± 5D (µg/g) | Food intake (g) | Daily I intake (µmol/day) | Urine Ic | Urine volume (g) | Faecal Ic | Faecal volume (g) | Urinary I:cr,†††§§ | Faecal I:||| 1 balance†††§§ |
|-----------|-------------------|----------------|---------------------------|---------|-----------------|-----------|------------------|---------------------|-------------------|-------------------|
| 1         | 0.15 ± 0.03       | 340.2          | 0.43a                     | 0.95a   | 279.7           | 4.18b     | 49.0             | 0.20a               | 71.9             | 46.7d             |
| 2         | 0.24 ± 0.02       | 373.2          | 0.67a                     | 1.58a   | 270.5           | 4.02a     | 60.2             | 0.23a               | 73.8             | 33.6c             |
| 3         | 0.46 ± 0.02       | 344.6          | 1.19a                     | 2.44ab  | 410.9           | 5.04a     | 54.3             | 0.27a               | 76.8             | 21.3b             |
| 4         | 1.06 ± 0.04       | 393.7          | 3.15a                     | 6.93b   | 347.7           | 8.90b     | 66.9             | 0.43ab              | 78.9             | 20.0b             |
| 5         | 3.09 ± 0.11       | 361.2          | 8.38a                     | 20.49c  | 306.0           | 12.53b    | 57.8             | 0.72b               | 80.0             | 6.6a              |
| 6         | 8.18 ± 0.23       | 359.0          | 22.10†                    | 41.09   | 294.2           | 30.81h    | 51.5             | 1.60††              | 86.6             | 6.9a              |
| 7         | 9.24 ± 0.25       | 341.8          | 23.62†                    | 62.02g  | 253.1           | 32.62g    | 51.7             | 1.69††              | 78.0             | 7.4a              |
| Pooled SEM | 29.4             | 0.88           | 1.73                      | 45.1    | 0.95            | 1.18      | 6.2              | 0.13                | 5.5              | 2.3               |

†Linear component significant (p < 0.05).
§§Quadratic component significant (p < 0.05).

*Data represent mean values of six cats for treatment 5–7; five cats for treatments 2–4 and three cats for treatment 1. Arithmetic means are presented in place of LS means due to inappropriate weighting as a result of the missing data.

‡‡Iodine added as KI. Concentrations shown are analysed values (DM basis).

I, iodine; KI, potassium iodide; DM, dry matter; LS, least squares.

Iodine intake in mg/kg BW0.67 is adequate (Delange and Ermans, 1991).

Mean values not bearing same superscript differ (p < 0.05).
HDPE vials. The dry food samples were analysed as received by uniformly mixing and then gravimetrically transferring aliquots (approximately 0.75 g) to HDPE vials. All samples were then analysed in duplicate by EINAA using the method previously reported by Spate et al. (1995).
Iodine balance (food, urine and faeces)
At week 24, urine, but not faeces was collected over two 3-day periods and urinary I concentrations were averaged between the two periods. At week 36, I balance was measured over a 7-day period with the collection of both faeces and urine. The I balance collection was conducted in three stages, with each group being staggered one week apart. Total faecal and urine collections were taken from each cat via a specialized litter box. A previous pilot study using an I standard and our litter box with plastic bead setup indicated a small loss of I in the beads (e.g. average recovery was 97%). Therefore, plastic beads and a deionized water rinse were also analysed for a more complete recovery of I. Prior to the 7-day balance period, cats were acclimated to plastic litter boxes and bead litter for a period of 7 days. The rinse was performed at the end of each 7-day period and the amount of water used for the rinse was recorded. Urine, faeces and a representative sample of food were collected daily over the 7-day period and were sent for I analyses. Faecal samples were freeze-dried and the moisture content was determined prior to I analyses. Urine collections from other time points (baseline, week 3, 6, 12, 18 and 48) were not 24 h collections, but were instead morning catch samples. Iodine analyses were performed as mentioned previously (EIN-AA) on duplicate samples of urine, freeze-dried faeces, de-ionized water rinse, plastic bead rinse and food. Iodine recovery in the plastic beads and water rinse averaged 6% of the total I measured.

Serum chemistries/CBC/urine creatinine
Complete biochemistry profiles and urinary creatinine were performed by an automated analyzer (Hitachi 912; Roche, Indianapolis, IN, USA). Complete blood counts were performed by an automated analyzer (Serona System 9000, ABX Diagnostics, Irvine, CA, USA) calibrated for dogs and cats.

Thyroid function diagnostics
Thyroid hormone profile analyses were performed at the Diagnostic Center for Population and Animal Health endocrine section at Michigan State University and included serum TT4, TT3 and free thyroxine (FT4) (two-step). Methods used were performed as described by Nachreiner et al. (2009). Cats were also tested for thyroidal uptake of 99mTcO4⁻ at Kansas State University and the thyroid to salivary uptake ratio was calculated as previously described by Henrikson et al. (2005). The normal reference range for T:S as defined by Henrikson was 0.48 to 1.66.

Statistical analyses
All analysis of variance and regression analyses were performed using the general linear models appropriate for a randomized complete block design using SAS statistic software (version 8, SAS Institute, Cary, NC, USA). In addition, a non-linear procedure of SAS (1999) was used to determine breakpoints using a model involving two linear splines with no plateau (Robbins, 1986) wherein the dependent variable was regressed on supplemental dietary I intake. This model was chosen as it gives a continuous broken line calculated by least squares and thus yields an objective estimate of the inflexion point. Treatment means were also compared among treatments using least square (LS) means and pre-planned linear, quadratic and cubic orthogonal contrasts were also determined. For the I balance data, only 36 out of 42 cat observations were used. (See I balance section under Results for more detailed explanation of missing data). Because of the unbalance due to missing data, LS means do not adjust correctly, thus arithmetic means were evaluated. Probability values of p < 0.05 between treatments were considered significant.

Results
I biomarkers
There were significant linear effects observed for serum, urine and faecal I, urinary I:creatinine ratio, I balance and significant linear and quadratic effects noted for T:S ratio (Figs 1–5; Tables 2–5).

Six month timepoint
No significant effects of dietary I were observed for bodyweight, serum chemistries, thyroid hormone profiles (not reported) or food intake (Table 2). Cats fed treatments 1–3 (0.17–0.47 mg I/kg diet) had serum I concentrations that were below reference ranges as defined for dogs (e.g. normal serum I = 0.05 µg/ml or 0.39 µmol/l; Puls, 1990). Urinary I concentration, when measured over a 24-h period, was also below reference range for cats fed treatments 1–2; treatments 3–7 equalled or exceeded the minimum urinary I concentrations defined for humans (e.g. minimum threshold for I adequacy (e.g. ≥100 µg/day or 0.13 µmol/day for the cat or 0.04 µmol I/kg body weight (BW)^0.67; Delange and Ermans, 1991). However, when urinary I was reported as concentration or corrected for creatinine, all treatments were above the minimum threshold.
described for humans (e.g. urinary I below 0.05 µg/ml or 0.39 µmol/l are reflective of populations at risk of cretinism; urinary I > 50 µg/g creatinine or 0.39 nmol I/mg creatinine are indicative of adequate I status (Delange and Ermans, 1991)). Urinary I expressed as a percentage of I intake increased linearly with increasing dietary I.

Fig. 2 Regression of thyroid:salivary ratio on iodine (I) intake (µmol/day) at week 51. A breakpoint was determined using a model involving two linear splines with no plateau. Each point (◊) represents an average of six cats with one exception; treatment 4 represents means of five cats. The x and y coordinates for the inflexion point determined for T:S ratio were 0.17 and 1.2 µmol/day respectively. The slope for T:S ratio above the inflexion point was 0.107 and below the inflexion point was 0.0007 (R² = 0.66). RDA, recommended dietary allowance.

Fig. 3 Daily urinary and faecal iodine (I, µmol/day) regressed on I intake (µmol/day) at week 36. Each point represents an average of six cats for treatments 5–7, five cats for treatments 2–4 and three cats for treatment 1. Urinary (▲) and faecal (●) I increased linearly (p < 0.05) with increasing I intake. Regression of urinary I and faecal I (y) on supplemental I concentration from KI (x) was y = –0.006 + 0.8181x (R² = 0.952), and y = 0.027 + 0.0641x (R² = 0.950) respectively.

Fig. 4 Regression of iodine (I) balance on I intake (µmol/day) at week 36 (7-day balance). Each point (●) represents an average of six cats for treatments 5–7, five cats for treatments 2–4 and three cats for treatment 1. Iodine balance increased linearly (p < 0.05) with increasing I intake. Zero I balance was achieved at 0.16 µmol/day or 0.44 mg I/kg diet (dry matter). Regression of I balance (y) on I intake from KI (x) was y = –0.022 ±0.063) + 0.1179 ±0.032)x, R² = 0.29.

Fig. 5 Regression of daily urinary iodine (I) expressed per kg BW0.67 on I intake (µmol/day) at week 36. Each point (●) represents an average of six cats for treatments 5–7, five cats for treatments 2–4 and three cats for treatment 1. The shaded region indicates desired normal range for urinary I as defined for humans (Delange and Ermans, 1991). Because of the body size difference between humans and cats, urinary I excretion is expressed on an equivalent BW0.67 basis. Treatments 3–5 [e.g. 0.46–3.1 mg I/kg diet, dry matter] fell within optimal range (e.g. 0.04–0.37 µmol I/kg BW0.67). For humans, I adequacy is defined as urinary I excretion ≥100 µg/day. The metabolic bodyweight equivalent for the cat equates to 17.1 µg/day or 0.13 µmol/day or 0.04 µmol/kg BW0.67. The calculations are based on the following: 70 kgBW0.67 = 17.2, 100 µg I/day/17.2 kg BW0.67 = 5.81 µg I/kg BW0.67. Multiply the cat’s metabolic equivalent bodyweight by the factor derived from the human requirement: 5 kgBW0.67 = 2.94; 5.81 × 2.94 = 17.1 µg I daily urinary I excretion. BW, body weight.
I breakpoint (scintigraphy)

A breakpoint or inflexion point for Tc\textsuperscript{99m} scintigraphy (T:S ratio) was measured both at week 20 and week 51. The estimates determined at both time points were similar [0.18 and 0.17 \( \mu \)mol/day at 6 and 12 months respectively (Figs 1 and 2)]. These intakes equate to a dietary concentration of 0.51 and 0.46 mg I/kg diet respectively (DM basis).

I balance

Food analyses during the 7-day balance period indicated that the wrong diet was fed for cats on treatment 1 for groups 1 and 2, thus only group 3 means for treatment 1 are presented (three observations). Two cats refused to use the litter box (one cat each on treatments 2 and 3) and one cat (treatment 4) died due to heart failure (i.e. unrelated to the study or food) prior to the I balance collection period. In addition, a number of cats had loose stools which may have affected recovery of I from faecal matter vs. urine. For this reason, both faecal and I balance data were evaluated with and without faecal data from cats having loose stools. Data from the intact dataset are presented because findings were not significantly different between these datasets. Seven-day I balance data are shown in Table 3, whereas daily concentrations are presented in Table 4.

Both urinary and faecal I were linear functions (p < 0.05) of I intake (Fig. 3; \( R^2 = 0.95 \) for both). This linear relationship between urinary I and I intake determined in our study is well established (Dietary Reference Intakes, 2001). Faecal I, however, is not frequently measured in humans because faecal excretion of I is considered negligible (Delange and Ermans, 1991). However, in our study (Tables 3 and 4), faecal I excretion ranged from 0.03–0.24 \( \mu \)mol/day (4–31 \( \mu \)g/day) and at low I intakes accounted for as much as 23–47% of total I intake.

I balance was a linear function of I intake (Fig. 4; \( R^2 = 0.29 \); linear (p = 0.0010). A minimum I requirement was determined from I balance data and was defined as the intake resulting in zero balance. This estimate was determined to be 0.16 \( \mu \)mol/day or 0.44 mg I/kg diet (DM basis).

Figure 5 compares daily urine I excretion obtained in our study for cats vs. normal ranges defined for humans (Delange and Ermans, 1991). Urinary I excretion is expressed on an equivalent BW\textsuperscript{0.67} basis, because of the body size difference between humans and cats. The allometric coefficient for lean body mass for the cat is 0.67 as opposed to 0.75, based on National Research Council (2006) guidelines. In agreement with NRC recommendations, our calculations confirmed that the BW conversion from human I guidelines to experimentally derived data for the cat fit closer using the coefficient 0.67 vs. 0.75; see Fig. 5 legend for calculations. Daily urinary I excretion was a linear function of I intake. Iodine intakes between 0.46 and 3.1 mg I/kg diet (treatments 3–5) fell within optimal I intakes for the cat as defined by 24 h urinary I excretion guidelines established for humans. Note that the minimum daily urinary I concentration that defines I adequacy (100 \( \mu \)g/day for humans or 0.04 \( \mu \)mol I/kg BW\textsuperscript{0.67}) occurred at a dietary intake of 0.46 mg I/kg diet. This estimate agrees closely with the estimate of the cat’s I requirement as defined by week 51 Tc\textsuperscript{99m} scintigraphy data and week 36 I balance (0.46 and 0.44 mg I/kg diet respectively).

Thyroid hormone profiles

There were no significant effects of varying I intake on total thyroxine (TT\textsubscript{4}) or total triiodothyronine (TT\textsubscript{3}). However, FT\textsubscript{4}, as measured by two step, was significantly lower at week 48 for cats fed the highest I concentration [quadratic effect; (p = 0.007); Table 5]. Consistent with this finding, there was a tendency for TT\textsubscript{4} and TT\textsubscript{3} to also be lower for cats fed the highest I intake (treatment 7).

General

There was no significant difference in weight gain (Table 5), feed intake (Tables 2, 3 and 5), serum chemistries or CBCs (not reported) as a result of varying I intake. In addition, no clinical signs of I deficiency or excess (goitre) were observed.

I Requirement and lowest observable adverse effect level

The experimentally-derived I requirement (\( \mu \)mol/day and mg I/kg diet) for the adult cat is superscripted in Table 6 (0.46 mg I/kg diet; DM basis) and was based on week 51 scintigraphy and week 36 daily urinary I concentration. In addition, there were significant changes observed between treatments 6 and 7, suggestive of possible early adverse effects, supportive of a LOAEL estimate. A significant decrease in FT\textsubscript{4} (quadratic effect (p = 0.007)) occurred at the highest I level (9.2 mg I/kg diet) and excretion of I appeared to be impaired. Combined urinary and faecal I excretion decreased from 94 to 85% resulting in a
Discussion

Minimum recommended allowance or lower limits

The requirement estimate determined at 12 months in our study (0.46 mg I/kg diet, DM basis; Table 6, Fig. 2) was lower than National Research Council (2006) recently proposed recommended allowance (1.4 mg I/kg diet, DM) for the cat. This estimate was, however, similar to minimum recommendations for the dog (Belshaw et al., 1975) and the RDA for humans (Dietary Reference Intakes, 2001). Based on changes in radioiodine metabolism, Belshaw recommended 140 μg as a minimum daily requirement for the dog. This daily intake equates to a dietary concentration of 0.56 mg I/kg diet. Similarly, the RDA (Dietary Reference Intakes, 2001) for humans is 150 μg/day, which on a metabolic equivalent basis equates, in the cat, to 0.20 μmol/day or 0.51 mg I/kg diet numbers that are in very close agreement to our experimentally-derived I estimates (0.17 μmol/day or 0.46 mg I/kg diet respectively). It should be noted that I requirement estimates, as determined using radioiodine or Tc²⁹⁹m (dog, cat and humans) are higher than I requirement estimates using prevention of clinical signs (thyroid hypothyreosis, poor hair coat, TT₄ reduction, increased thyroid stimulating hormone (TSH), decreased weight gain or food consumption). For example, the I requirement for the rat and pig (0.15, 0.14 mg I/kg diet respectively) was determined based on minimum level of I that in some cases of 1) clinical signs of I deficiency (e.g. thyroid hypothyreosis, poor hair coat, decreased bodyweight and/or food intake, myxoedema, lethargy) and/or 2) changes in thyroid hormone profiles must be less than 0.15–0.17 mg I/kg diet (lowest level of I fed in our study) for the adult cat because none of these were observed in our study.

Note that multiple I requirement estimates were derived from our study (e.g. different time points and different biomarkers), but ultimately, the adult cat I requirement estimate was based on three measurements (e.g. week 51 scintigraphy data (Fig. 2), week 36 daily urinary I concentration (Table 4, Fig. 5) and zero I balance (Fig. 4). These three estimates were chosen for the following reasons: Scintigraphy data from week 51 was chosen over week 20 because: 1) adaptation to varying nutrient intake can take several months or longer to occur, thus 1 year data is more defendable. 2) two out of the three markers used to define the I requirement (e.g. week 51 scintigraphy and week 36 daily urinary I concentration) were in agreement and only slightly higher (but not significantly different) than the estimate yielded from the I balance data (e.g. 0.46 vs. 0.44 mg I/kg diet; Figs 2, 4 and 5) and 3) as a general rule of thumb, when multiple markers are used to arrive at an estimate, the highest estimate is used as it ensures all metabolic needs are met.

Four key factors need to be met to determine a definitive nutrient requirement estimate (Baker, 1986) including: 1) evaluation of a sufficiently wide enough range of intakes to define both a linear and plateau response curve, 2) use of appropriate and sensitive biomarkers for assessing nutrient status, 3) sufficiently long enough period to allow for adaptation and 4) use of a nutritionally balanced diet with sufficient nutrients of other elements to allow for metabolic needs. A number of other studies have suggested higher minimum I recommendations for the cat approximating 2–4 mg I/kg diet (Scott et al., 1961; Smith, 1996; Ranz et al., 2002; Meyer and Heckötter, 1986), but these studies failed to meet one or more of the criteria listed above.

Table 6 Dietary I concentration and daily iodine amounts for maintenance for an adult cat

<table>
<thead>
<tr>
<th>mg I/kg diet</th>
<th>μmol/day</th>
<th>μmol/kg BW</th>
<th>μmol/kg BW²⁶⁷</th>
<th>μmol I/1000 kcal ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum requirement</td>
<td>0.46†</td>
<td>0.17†</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>LOAEL‡</td>
<td>9.2‡</td>
<td>3.35‡</td>
<td>0.67</td>
<td>1.16</td>
</tr>
<tr>
<td>LOAEL§</td>
<td>5.8</td>
<td>2.28</td>
<td>0.46</td>
<td>0.79</td>
</tr>
</tbody>
</table>

BW, body weight; ME, metabolizable energy; DM, dry matter; FT₄, free thyroxine; LOAEL, lowest observable adverse effect level; I, iodine.

*Data determined in study involved 41 cats fed varying intakes of I for 12 months. Average age of cats at beginning of study was 8.1 years. Average weight of adult cats = 4.89 kg, average daily food intake = 50.2 g, energy density of the diet = 4.2 kcal ME/g DM, average ME intake = 211.1 kcal.

†Values represent primary data determined from study.
‡Lowest observable adverse effect level (LOAEL) derived from study base on significant changes between treatments 6 and 7 for FT₄ suggesting hypothyroid function (noted in Table 5) and increased I balance (Table 3) as result of impaired urinary I excretion.
§Lowest observable adverse effect level (LOAEL) in humans = 1700 μg/d (DRI, 2001); when this value is extrapolated to the cat on an equivalent metabolic BW basis (BW²⁶⁷), this equates to 5.8 mg I/kg diet for the cat.

significant increase in I balance (e.g. 1.37 to 3.57 μmol). The requirement and LOAEL estimates for I when expressed on a BW basis, BW²⁶⁷ and per 1000 kcal ME were also calculated from these experimentally-derived estimates.
Feline iodine requirement
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The diet used to define the I requirement in our study would be considered a practical, commercial-type diet as opposed to a purified or semi-purified diet typically used to define nutrient requirements. Replacement of vegetable protein for animal protein, in addition to usage of non-iodized salt and I-free mineral mix was critical in achieving the low basal I concentration. This diet also contained approximately 30 mg/kg diet isoflavone. The association between soybean and goitre has been well described (Doerge and Sheehan, 2002). Genistein is the major isoflavone in soybean and possesses both estrogenic and goitrogenic activity (Doerge and Sheehan, 2002). In humans, goitre has been seen in infants fed soy formula; this is usually reversed by changing to cow milk or I-supplemented formulas. Iodine deficiency is necessary for soy to cause antithyroid effects (Doerge and Sheehan, 2002).

For example, it was demonstrated by Sihombing et al. (1974) that in the absence of I (I concentration was 0.04 and 0.03 mg I/kg diet in the soy and casein diet respectively), thyroid weights were greater for pigs fed soy vs. those fed casein diets. However, in the presence of I (0.2 mg I/kg diet), protein source had no effect on thyroid weight. Similarly, other studies in our laboratory (K. J. Wedekind, R. F. Nachreiner, unpublished) comparing titrated levels of soybean meal (8–18%) to diets without soybean meal (0.21–0.29 mg I/kg diet) showed little goitrogenic effect of soy on thyroid hormone function or animal performance. Thus, it is our opinion that the I estimate derived from our study would not be increased in the presence of increased soy or other goitrogen and represents a minimum recommended allowance that would be applicable to commercial cat foods (i.e. no bioavailability factor needs to be applied) as opposed to a ‘minimal requirement estimate’ which typically are derived from experimental studies employing semi-purified or purified diets.

According to the dietary reference intake for humans (Dietary Reference Intakes, 2001), important measures of I status include: 1) radiiodine accumulation and turnover, 2) urinary I, 3) thyroid size, 4) I balance, 5) TSH, 6) serum thyroglobulin and 7) T4 and T3 assays.

Scintigraphy

The normal thyroid gland takes up the amount of circulating I necessary to meet the body’s need for thyroid-hormone synthesis. In deficiency, the thyroid gland concentrates more radioactive I, whereas in I adequacy and excess, less radioactive I is taken up. In the Belshaw et al. (1975) study, significant changes in radiiodine metabolism occurred between 90 and 140 µg/day, (e.g. 1.10 µmol/day or 0.07 µmol/kg BW) suggesting dietary I intakes below 140 µg/day were insufficient to maintain normal I thyroid kinetics. In our study, uptake of Tc99m, which mimics I uptake, was significantly elevated at dietary intakes below 0.18 µmol/day or 0.05 µmol/kg BW (Figs 1 and 2), but yielded a plateau response at higher I intakes.

Urinary I

In our study, measurements of urinary I were nearly always linear (Figs 3 and 5; Tables 2–5) with respect to dietary I intake. Even in the few instances where urinary I concentration (µmol/l) was shown to have a significant quadratic component (week 18 (not shown) and week 24 (Table 2), it was considerably smaller than the linear component. Thus, we were not able to define an inflexion point or I requirement estimate based on urinary I excretion. However, in humans, the following guidelines for assessing I status or adequacy have been established for each of these urinary I criteria. These guidelines appear to be valid for the cat, except that in the case of 24-h urinary I excretion, these values need to be expressed per kg BW0.67 to be applicable. Similarly, I requirement estimates for humans and cats agreed closely when expressed per kg BW0.67.

As cited by Delange and Ermans (1991), the human guidelines for I status are as follows: mean values of urinary I below 5 µg/dl (e.g. 0.39 µmol/l) are reflective of populations at risk of cretinism; urinary I concentrations greater than 50 µg/g creatinine (e.g. 0.39 nmol I/mg Cr) are indicative of adequate I status; and median 24-h urinary I excretion >100 µg/day is adequate (equates to 0.04 µmol I/kg BW0.67). Laurberg et al. (2001) suggested the following classification for 24 h urinary I concentrations to define severity or adequacy of I status: <25 µg or 0.01 µmol I/kg BW0.67 is indicative of severe I deficiency; between 25–60 µg (0.01–0.03 µmol I/kg BW0.67) suggests moderate I deficiency, between 60–120 µg (0.03–0.06 µmol I/kg BW0.67) suggests mild I deficiency and 24 h concentrations between 120–220 µg (0.06–0.10 µmol I/kg BW0.67) suggests optimal I intake. Likewise, normal serum I ranges for the dog (Puls, 1990) have been reported to be greater than 5 µg/dl (e.g. 0.39 µmol/l).

Viewing all of these guidelines as a whole, there was generally good agreement between the published guidelines for humans and dogs vs. the serum and urinary concentrations reported in our cat study. Dietary I intakes less than 0.46 mg I/kg diet yielded 24 h urinary I and serum I concentrations...
that would be considered marginal or below optimum relative to the guidelines established for assessing I adequacy. Urinary I concentrations (μmol/l or nMol I/mg Cr), however, suggested all seven treatments were adequate. The 24 h urinary guidelines defined by Laurberg et al. (2001) disagreed somewhat with our findings (e.g. our cat’s I requirement estimate at 0.46 mg I/kg diet yielded a 24-h urinary I excretion of 0.13 μmol/day or 0.04 μmol I/kg BW0.67). According to Laurberg, this concentration would be defined as a mild deficiency, but this concentration was defined as adequate according to guidelines published by Delange and Ermans (1991). These guidelines for both humans and dogs add further validity to our experimentally-determined I requirement estimates.

Urinary I is an important measure of I status. However, the most accurate way to measure urinary I excretion is still debated (Knudsen et al., 2000). The choice among methods depends on the intended application, the number of samples, cost and technical capability. Perhaps the biggest criticism is using single casual collections of urinary I concentration to predict I intake of a population. Urinary I concentration varies considerably from day to day as well as within a day. For example, fasting morning samples were shown to underestimate I status in a human population (Rasmussen et al., 1999). The morning catch samples taken throughout our study may not be as representative of I status as the 24-h collections measured during the I balance collection periods which were collected over multiple days. Despite these limitations, I intake was controlled in this study, so urinary I variability should be lessened in this situation. In addition, presenting urinary I measurements in multiple ways provides useful information for establishing normal reference ranges given that 24-h urinary collections may not be practical in certain situations. Lastly, only the 24-h urinary I measurement was used in estimating the cat’s I requirement.

I balance

In humans, daily I intake is frequently calculated from 24 h urinary I concentrations (e.g. Urinary I (μg/l) × 0.0235 × wt (kg) = Daily I intake; Dietary Reference Intakes (2001)). The linear relationship between urinary I excretion and I intake determined in our study for cats was as follows (9 month data): 1) μmol/l urinary I (not shown): Y = −0.287 + 18.468X, R² = 0.96; 2) μmol I/mg creatinine (not shown): Y = 0.252 + 5.361X, R² = 0.80; 3) 24 h urinary I (μmol/day; Fig. 3): Y = −0.006 + 0.8181X, R² = 0.95. In humans living in non-endemic areas, the daily urinary excretion of I is at least 100 μg/day (Delange and Ermans (1991) or 0.04 μmol I/kg BW0.67. In countries with adequate I intakes, urinary I excretion generally accounts for 90% or more of I intake. In our study, urinary I excretion as a percent of I intake was linear at 6 months (Table 2) but not at 9 months and averaged 78% (Table 3). Our finding that faecal I (μmol/day or μmol/l or faecal I expressed as a percentage of I intake) is a linear function of I intake (Tables 3–4; Fig. 3) contrasts with those of Ranz et al. (2002). In their study, they concluded that faecal I excretion in cats was independent of I intake and estimated 24 h faecal I excretion at 65 μg/day (0.51 μmol/day). Much higher intakes of I (41–191 μg I/kg BW/24 h or 0.32–1.51 μmol I/kg BW/24 h) and short study duration (54 d total; 7-d only for each dietary I concentration) were evaluated in the Ranz study, which may explain the discrepancies between their study and ours. Assuming a cat BW equal to 5 kg, I intake in the Ranz et al. (2002) study, ranged from 204–955 μg/day (e.g. 1.61–7.53 μmol/day). Faecal I concentrations in our study ranged from 4–31 μg/day (e.g. 0.03–0.24 μmol/day). Our estimates of 24-h urinary I (for cats fed similar I intakes (treatment 6 and 7); Tables 2–4) were similar to daily urinary I measured by Ranz et al. (2002). According to their study, 100 μg/day I (or 20 μg I/kg BW/24 h) was estimated as a minimum I intake needed to maintain positive I balance. Conversely, our findings suggest zero I balance can be maintained at intakes as low as 20.7 μg/day I (or 0.16 μmol/day or 0.04 μmol I/kg BW0.67 or 0.44 mg I/kg diet (DM basis; Fig. 4).

It was observed during the 7-day balance period (week 36) that the percentage of I excreted in urine (72–86%) and faeces (47–7%; as a percent of I consumed, faecal I decreases with increasing I intake), together, was greater at low or optimal I intakes (e.g. ≥100% for treatments 1–4, vs. 85–94% for intakes approaching or exceeding the cat’s upper I limit). These percentages were not significantly altered by inclusion or exclusion of cats having loose stools, thus, we think these estimates of I excretion are accurate. In fact, for adult animals, the nutrient requirement can be defined as the intake which results in zero balance, so urinary and faecal I excretion would be expected to exceed 100% at intakes below the requirement and our estimate of I intake necessary to achieve zero I balance (0.44 mg I/kg diet) was remarkably similar to our other estimates of the cat’s I requirement (thyroid scintigraphy and 24 h urinary I excretion).
Our estimates of I excretion for cats consuming adequate (1 mg I/kg diet; 99%) or high I intake (3–9 mg I/kg diet; 85–94% of I intake for urine and faeces combined) are similar to numbers cited for humans (e.g. urinary excretion of I generally accounts for 90% or more of I intake). Faecal excretion data, however, is lacking in humans, but given the similarities observed in our study for urinary I and I requirement estimates between cats and people, percentage I excretion in faeces is probably also similar.

Although 7-day I balance was negative for treatments 1 and 2 (e.g. −0.07 and −0.04 μmol/day), these estimates are not significantly different from zero. Furthermore, according to Delange and Erman (1991), as long as I intake is maintained above an I threshold of 50 μg/day (metabolic equivalent for the cat is 0.18 mg I/kg diet), normal I metabolism is maintained without risk of goitre or clinical signs of I deficiency. This finding that 0.18 mg I/kg diet may be a critical threshold for the cat is supported by the fact that after 1-year duration, even at our lowest I intake evaluated (0.15–0.17 mg I/kg diet), low I intake had no effect on food intake, BW, or thyroid hormone profiles. In addition, there were no clinical signs such as goitre observed in our study.

**TSH and thyroid hormone profiles**

In humans, TSH assays have been widely available for approximately two decades and serum TSH is the preferred test for assessing thyroid function (Dietary Reference Intakes, 2001). For cats, however, a feline TSH assay is not yet available and use of canine-specific TSH in our experience has been somewhat insensitive. Thus, thyroid hormone profiles (e.g. TT₄, TT₃, FT₄ and FT₃) are the standard for assessing thyroid function in cats. In our study, there was a significant reduction (e.g. quadratic effect; p = 0.007) in FT₄ at week 48 for cats fed the highest I intake (Table 5) and a tendency for TT₄ and TT₃ to also be lower. This effect on FT₄ was not observed at earlier time points in the study. According to Laurberg et al. (2001), excessive intakes of I (e.g. >800 μg urinary I per 24 h; >0.37 μmol I/kg BW⁰.⁶⁷) are associated with a higher prevalence of thyroid hypofunction in humans. Note, however, that we did not observe suppressed FT₄ (nor TT₄ or TT₃) for cats fed treatment 6, despite the fact that their urinary I excretion (0.93 μmol I/kg BW⁰.⁶⁷) was indicative of excessive I intake and all thyroid hormone profiles measured at week 48 and throughout the study were within normal reference range.

**Proposed safe upper limit**

In humans, the NOAEL and LOAEL for I is 1000 and 1700 μg/day respectively (Dietary Reference Intakes, 2001). As our data confirm that I requirement estimates and urinary I excretion agree closely between humans and cats (when expressed on a metabolic equivalent basis; BW⁰.⁶⁷), it seems reasonable to use, or at least compare, human guidelines for establishing safe upper limits for the cat. Thus, using human guidelines, the calculated NOAEL and LOAEL levels for the cat would be 3.4 and 5.8 mg I/kg diet respectively (Table 6). These suggested I upper limits for the cat are further supported by other human guidelines (Laurberg et al., 2001) which suggest treatments 6 and 7 in our study exceeded optimal intake (Table 4). Listed below are Laurberg et al. (2001) guidelines for 24 h urinary I excretion (in parentheses are these same ranges expressed on a BW⁰.⁶⁷ basis): median 24 h urinary I between 220–400 μg (0.10–0.19 μmol/day) is considered a mild I excess for the elderly, between 400–800 μg (0.19–0.37 μmol/d) is considered a mild I excess for adults and elderly; and 24 h urinary I concentrations >800 μg (>0.37 μmol/day) are indicative of severe I excess.

Evidence from our study, suggest that the highest I concentration fed (e.g. treatment 7 provided 8.8–9.2 mg I/kg diet) could also be used as a basis for establishing a LOAEL level for the cat. At this highest I intake, hypothyroid function was observed (significant quadratic effect for FT₄; numerically lower TT₄ and TT₃ at week 48). These changes in thyroid function were not observed at earlier time points and only observed for treatment 7. Because I homeostasis is controlled more by excretion than through absorption, perhaps this highest dose is beginning to overwhelm the excretory systems, resulting in excess retention of I which then leads to changes in thyroid function. Note that I balance data showed a significant increase in I retention between treatments 6 and 7, whereas faecal and urinary I excretion was not significantly different. In humans, 10× of the I requirement can cause hypothyroid function (Pennington, 1990); our study suggested a LOAEL for cats at 20× of the requirement.

**Summary**

The I requirement for the adult cat provided as KI in a corn gluten meal-corn based diet is 0.46 mg I/kg diet (DM basis). This is in close agreement with the I requirement determined for dogs (140 μg/day which
equates, in the cat, to 0.56 mg I/kg diet; Belshaw et al., 1975) and humans (150 µg/day which equates, in the cat, to 0.51 mg I/kg diet; Dietary Reference Intakes, 2001). This estimate is much lower than the proposed National Research Council, 2006 recommended I allowance for cats (1.4 mg I/kg diet), but is higher than current AAFCO (2008) minimum I recommendations for the adult cat (0.35 mg I/kg diet).

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