PETITION

To the
U.S. Department of Agriculture
National Organic Program

To Amend 7 CFR §205.603(d)
To Include Required Amino Acids
As A Synthetic Substance Allowed
For Use in Organic Pet Food Production

Submitted January 30, 2012

By
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January 18, 2012

Miles McEvoy
Deputy Administrator
USDA/AMS/TMP/NOP
1400 Independence Ave., S.W.
Room 2646-S
Ag Stop 0268
Washington, D.C. 20250-0201

Dear Mr. McEvoy,

The Pet Food Institute (PFI), the trade association comprised of pet food manufacturers which produce 98% of the dog and cat sold in the United States, an $18 B business with an additional $1.2B in exports, formally submits this petition to the U.S. Department of Agriculture’s National Organic Program. We request the amendment of §205.603(d) of the National Organic Standards to include required amino acids as synthetic substance allowed for use in organic pet food production on behalf of all Organic pet food producers in the U.S. This petition is being submitted in anticipation of the development of formal regulations governing the certification of pet food under the National Organic Standards.

In accordance with the instructions on the National Organic Program website, we have provided answers to all of the questions below, and in a manner that satisfies the criteria in 7 USC 6517 and 6518, commonly known as the Organic Foods Production Act.

We, of course, are ready to provide any additional information that you, the National Organic Standards Board, or the Technical Advisory Panels may require to complete your review process.

Sincerely,

Nancy K. Cook
Vice President

www.petfoodinstitute.org
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Petition Information

Overview and Introduction

The U.S. Department of Agriculture’s National Organic Standards recognized from the outset that vitamins, minerals and other required nutrients are essential in formulating certified organic products that will meet the nutritional requirements of humans and animals.

Specifically, §205.603(d)(2) and §205.603(d)(3) allow trace minerals and vitamins to be utilized in livestock for enrichment or fortification when FDA approved. Those nutrients are allowed for use in livestock feed regardless of the method of manufacturing or handling.

Under the current regulations, pet food products seeking certification under the USDA Organic Standards must be produced in accordance with §205.605 and §205.606 of the National Organic Standards. However, this petition is being submitted in anticipation of proposed regulations to allow certification of pet food as organic under §205.603 of the National Organic Standards.

This petition is also being submitted in accordance with the consent of the National Organic Standards Board Livestock Committee—and the National Organic Program—to consider a petition for required nutrients as defined by the National Research Council in the National Academy of Science’s Nutrient Requirements of Dogs and Cats.

That decision is consistent with the information supplied to the National Organic Program on June 27, 2011 by the U.S. Food and Drug Administration’s (FDA) Center for Veterinary Medicine (CVM). In that communication, the FDA stated, “The CVM relies on the various ad hoc expert nutrition committees under the Committee on Animal Nutrition of the National Research Council in the National Academy of Sciences for establishment of which nutrients, and in what amounts, are essential in the diets for specific species of domestic animals to meet that species' daily nutrient requirements. For dogs and cats, the required essential nutrients are listed and described in the 2006 edition of Nutrient Requirements of Dogs and Cats. The CVM considers the nutrients listed in Tables 15-3,15-5, 15-8, for dogs, and Tables 15-10, 15-12,15-14 for cats, to be essential nutrients and eligible for supplementation if required to meet and provide the listed MR, or in the absence of a stated value for the MR then the listed value for AI for that nutrient, in products represented to be “complete and balanced.”

Note - The tables referenced above at included with this petition as Attachment D.

State regulators utilize the Official Publication of the Association of American Feed Control Officials (AAFCO) as a model for the regulation of pet food products, including the nutrient
composition of products eligible to be labeled as “complete and balanced.” As explained in the FDA’s June 2011 memorandum, “The AAFCO Dog and Cat Food Nutrient Profiles do not contain any nutrient that has not been determined to be essential and listed in the previously referenced tables in the 2006 edition of Nutrient Requirements of Dogs and Cats.”

Accordingly, this petition request approval for the addition of amino acids to add a section §205.603(d)(3) stating “For dogs and cats, synthetic amino acids defined as required by the National Research Council of the National Academy of Sciences.”

While this petition requests the allowance of those materials as a category—consistent with the language in §205.603(d)(2) and §205.603(d)(3), these amino acids are discussed individually to the extent possible throughout this document.

The importance for consideration of all of these required amino acids cannot be understated. Unlike humans, dogs and cats rely on their daily ration of commercially-prepared pet food as their sole source of nutrition. The absence of any of these required amino acids will have a serious detrimental effect upon the health of that pet.

1. The substances’ common names

This petition covers the category of required amino acids. Amino acids categorized as required by the National Research Council’s Nutrient Requirements of Dogs and Cats include all of the following:

- Arginine
- Methionine
- Cysteine
- Lysine
- Taurine
- Tryptophan
- Threonine
- Histidine
- Isoleucine
- Leucine
- Phenylalanine
- Tyrosine
- Valine

2. The official name, address, and telephone number for Pet Food Institute:

Pet Food Institute
2025 M St., NW
Suite 800
Washington, D.C. 20036
Tel: 202 367-1120
3. The intended or current use of the substance:

The above-listed amino acids are required in the diets of canine and felines. Without the inclusion of the proper levels of these amino acids, dog and cat food formulations cannot be classified as “complete and balanced” under the guidelines of the American Association of Feed Control Officials (and, which guidelines are based upon the NRC Nutrient Requirements of Dogs and Cats). As mentioned above, State regulators utilize the Official Publication of the Association of American Feed Control Officials (AAFCO) as a model for the regulation of pet food products. Accordingly, commercially-produced pet food products cannot be labeled as “complete and balanced unless those products contain the required amino acids in the minimum (and maximum) levels listed in the tables below:

<table>
<thead>
<tr>
<th>AAFCO Dog Food Nutrient Profiles</th>
<th>Based on Dry Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Growth &amp; Adult</td>
</tr>
<tr>
<td>Units DM</td>
<td>Reproduction</td>
</tr>
<tr>
<td></td>
<td>Maintenance</td>
</tr>
<tr>
<td>Basis</td>
<td>Minimum</td>
</tr>
<tr>
<td>Arginine %</td>
<td></td>
</tr>
<tr>
<td>Histidine %</td>
<td></td>
</tr>
<tr>
<td>Isoleucine %</td>
<td></td>
</tr>
<tr>
<td>Leucine %</td>
<td></td>
</tr>
<tr>
<td>Lysine %</td>
<td></td>
</tr>
<tr>
<td>Methionine-cystine %</td>
<td></td>
</tr>
<tr>
<td>Phenylalanine-tryosine %</td>
<td></td>
</tr>
<tr>
<td>Threonine %</td>
<td></td>
</tr>
<tr>
<td>Tryptophan %</td>
<td></td>
</tr>
<tr>
<td>Valine %</td>
<td></td>
</tr>
</tbody>
</table>
### AAFCO Dog Food Nutrient Profiles

**Based on Calorie Content**

<table>
<thead>
<tr>
<th></th>
<th>Growth &amp; Reproduction</th>
<th>Adult Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units per 1000 kcal ME</strong></td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Arginine</td>
<td>g</td>
<td>1.77</td>
</tr>
<tr>
<td>Histidine</td>
<td>g</td>
<td>0.63</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>g</td>
<td>1.29</td>
</tr>
<tr>
<td>Leucine</td>
<td>g</td>
<td>2.06</td>
</tr>
<tr>
<td>Lysine</td>
<td>g</td>
<td>2.20</td>
</tr>
<tr>
<td>Methionine-cystine</td>
<td>g</td>
<td>1.51</td>
</tr>
<tr>
<td>Phenylalanine-tryosine</td>
<td>g</td>
<td>2.54</td>
</tr>
<tr>
<td>Threonine</td>
<td>g</td>
<td>1.66</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>g</td>
<td>0.57</td>
</tr>
<tr>
<td>Valine</td>
<td>g</td>
<td>1.37</td>
</tr>
</tbody>
</table>

### AAFCO Cat Food Nutrient Profiles

**Based on Dry Matter**

<table>
<thead>
<tr>
<th></th>
<th>Growth &amp; Reproduction</th>
<th>Adult Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units DM Basis ME</strong></td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Arginine</td>
<td>%</td>
<td>1.25</td>
</tr>
<tr>
<td>Histidine</td>
<td>%</td>
<td>0.31</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>%</td>
<td>0.52</td>
</tr>
<tr>
<td>Leucine</td>
<td>%</td>
<td>1.25</td>
</tr>
<tr>
<td>Lysine</td>
<td>%</td>
<td>1.20</td>
</tr>
<tr>
<td>Methionine-cystine</td>
<td>%</td>
<td>1.10</td>
</tr>
<tr>
<td>Methionine</td>
<td>%</td>
<td>0.62</td>
</tr>
<tr>
<td>Phenylalanine-tryosine</td>
<td>%</td>
<td>0.88</td>
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<tr>
<td>Phenylalanine</td>
<td>%</td>
<td>0.42</td>
</tr>
<tr>
<td>Threonine</td>
<td>%</td>
<td>0.73</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>%</td>
<td>0.25</td>
</tr>
<tr>
<td>Valine</td>
<td>%</td>
<td>0.62</td>
</tr>
<tr>
<td>Taurine (Dry Food)</td>
<td>%</td>
<td>0.10</td>
</tr>
<tr>
<td>Taurine (Wet Food)</td>
<td>%</td>
<td>0.20</td>
</tr>
</tbody>
</table>

### AAFCO Cat Food Nutrient Profiles

**Based on Calorie Content**

<table>
<thead>
<tr>
<th></th>
<th>Growth &amp; Reproduction</th>
<th>Adult Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Units per 1000 kcal ME</strong></td>
<td>Minimum</td>
<td>Minimum</td>
</tr>
<tr>
<td>Arginine</td>
<td>g</td>
<td>3.10</td>
</tr>
<tr>
<td>Histidine</td>
<td>g</td>
<td>0.78</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>g</td>
<td>1.30</td>
</tr>
<tr>
<td>Leucine</td>
<td>g</td>
<td>3.10</td>
</tr>
<tr>
<td>Amino Acid</td>
<td>g</td>
<td>3.00</td>
</tr>
<tr>
<td>---------------------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Methionine-cystine</td>
<td>g</td>
<td>2.75</td>
</tr>
<tr>
<td>Methionine</td>
<td>g</td>
<td>1.55</td>
</tr>
<tr>
<td>Phenylalanine-tryosine</td>
<td>g</td>
<td>2.20</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>g</td>
<td>1.05</td>
</tr>
<tr>
<td>Threonine</td>
<td>g</td>
<td>1.83</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>g</td>
<td>0.63</td>
</tr>
<tr>
<td>Valine</td>
<td>g</td>
<td>1.55</td>
</tr>
<tr>
<td>Taurine (Dry Food)</td>
<td>g</td>
<td>0.25</td>
</tr>
<tr>
<td>Taurine (Wet Food)</td>
<td>g</td>
<td>0.50</td>
</tr>
</tbody>
</table>

These materials are petitioned as a category for use as a synthetic allowed substance under §205.603(d) of the National Organic Standards.

The Organic Pet Food Recommendation unanimously adopted by the NOSB in November 2008 contained an appendix listing materials for possible petition to the National List for use in pet food. That appendix specifically listed the following amino acids for petition as allowed feed additives under §205.603(d):
- L-arginine - for pet food (amino acid)
- D-L Methionine for pet food (amino acid)
- Carnitine for pet food (amino acid)
- L-cysteine for pet food (amino acid)
- L-lysine, L-lysine monochloride for pet food (amino acids)
- Taurine for pet food (amino acid)
- L-tryptophan for pet food (amino acid)

Because the absence of even one required amino acid prohibits a pet food product from being labeled as complete and balanced, the National Organic Program and the National Organic Standards Board have consented to consider required amino acids as a categorical addition to the National Organic Standards. Accordingly this petition includes all forms to the required amino acids as identified by the National Research Council and as listed in the Official Publication of AAFCO.

However, the list contained in the Appendix of the National Organic Standards Board recommendation identifies those amino acids that are not readily available from agricultural products used in commercially-manufactured pet food products. The other required amino acids not listed in the NOSB recommendation are available in agricultural products and will not need to be utilized in a synthetic format.

4. A list of activities for which the substance will be used – mode of action

Activities
Accordingly, these required amino acids will be used as an ingredient in the following products to be manufactured as “organic” or “made with organic:”

- Wet cat food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction;
- Semi-moist cat food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction;
- Dry cat food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction;
- Wet dog food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction;
- Semi-moist dog food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction;
- Dry dog food formulations labeled as complete and balanced for adult maintenance, and for growth and reproduction; and
- Pet Treats.

**Mode of Action**

Comprised of 23 different amino acids, proteins are often called the “building blocks” of the tissues. The bodies of dogs and cats can manufacture 13 of these amino acids. The other 10 amino acids, however, must come from dietary meat and plant sources and are called the “essential amino acids”. The biological value of a protein is a measure of that protein’s ability to supply amino acids, particularly the 10 essential amino acids, and to supply these amino acids in the proper proportions.

Additionally, Taurine, Cysteine and Tyrosine, are recognized by the National Research Council as required amino acids. The reasons for inclusion for these three materials are explained in the following sections of the NRC:

**Cysteine:**

“Cysteine is an important component of proteins for their secondary structure and a major constituent of hair and glutathione. Since methionine serves as a precursor to cysteine, cysteine is a dispensable amino acid. Because cysteine is made only from methionine and can provide about one-half of the total need for sulfur amino acids, cysteine and methionine must both be considered when establishing the total sulfur amino acid requirement. Therefore, the requirements are presented as the MR of methionine when there is excess cysteine in the diet, and the total sulfur amino acid requirement, which can be met with only methionine, but commonly involves a combination of methionine and cysteine. Cysteine cannot be converted to methionine; so the MR of methionine must be met with methionine.” (NRC, 2006, Page 126)

**Taurine:**

“Taurine is a β-aminosulfonic acid (2-aminoethanesulfonic acid), an essential dietary nutrient for cats but dispensable for dogs fed adequate quantities of sulfur-containing...
Taurine is one of the most abundant free amino acids in mammals, being particularly high in brain, heart, and skeletal muscle. Peak concentrations of taurine occur in the total body of newborns and in neonatal brain and gradually decrease by 75 percent as cats mature, but 10 mmol taurine-kg\(^{-1}\) is maintained in several tissues in adult cats (Sturman, 1988).

“Since taurine does not contain a carboxyl group and is a β-amino acid, it is not found in proteins and is made in most species from cysteine. The synthesis of taurine appears to be severely limiting for strict carnivores, but not for most herbivores or omnivores.”

“Taurine deficiency causes a multitude of metabolic aberrations and clinical signs. Taurine is involved in fetal development, growth, reproduction, neuro-modulation, sight, hearing, heart function, osmoregulation, fat emulsification, neutrophil function, immune response, antioxidation, and bile acid and xenobiotic conjugation and acts as an anticonvulsant.” (NRC, 2006, Page 134)

**Tyrosine:**

“Although tyrosine is a dispensable amino acid, it is made in animals only from phenylalanine, and tyrosine spares about one-half of the phenylalanine needed by all species examined including dogs and cats. Thus, it is appropriate to consider the amount of phenylalanine required as the sum of phenylalanine plus tyrosine, provided the level of tyrosine in the diet is not higher than that of phenylalanine. Phenylalanine and tyrosine have not been shown to be the most limiting amino acids for growth or nitrogen balance in diets sufficient in protein or in commercial diets formulated using natural ingredients for dogs and cats.” (NRC, 2006, Page 128)

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5. **The source of the substance and a detailed description of its manufacturing or processing procedures from the basic component(s) to the final product.**

**Source:**

Amino acids are present in all proteins. However, purified proteins or purified amino acids, when fed alone without other food ingredients, cannot maintain dogs and cats in good health.

**Manufacturing Process:**

There are four general ways to obtain amino acids for commercial use: extraction from natural sources, chemical synthesis, fermentation, and enzymatic catalysis.

**Extraction from Natural Sources**

In extraction from natural sources the standard procedure is hydrolysis with aqueous acid, followed by capture of the amino acids by passage of the hydrolysate over a strongly acidic ion exchange resin. After the resin is washed with water, elution with aqueous ammonia frees the amino acids, which are collected in fractions. Extraction is the most

**Chemical Synthesis**

The advantage of a chemical synthesis is that it can be carried out on a very large scale, and often in a continuous way. The great disadvantage, however, is that it typically gives a racemic mixture of the enantiomeric forms of the amino acid. Thus the product of a chemical synthesis must be resolved into the \(R\) and \(S\) forms, followed by recovery and recycling via racemization of the undesired enantiomer.

An example of a chemical synthesis is provided by the preparation of \((R,S)-\)methionine. Since both the \(R\) and \(S\) isomers of methionine can be metabolized by poultry and swine, resolution is not necessary and, in contrast to most other amino acids, chemical synthesis is predominant for the industrial production of methionine, as well as for racemic alanine and glycine.

The first step of the chemical synthesis of methionine is the conjugate addition of methyl mercaptan to acrolein to give \(\beta\)-methylthiopropionaldehyde.

The addition of methyl mercaptan to acrolein takes place by a nucleophilic mechanism. Attack of the conjugate base of methyl mercaptan \((pK_a = 10.7)\) gives a resonance-stabilized anion, which then accepts a proton on carbon to give the addition product, \(\beta\)-methylthiopropionaldehyde.

\(\beta\)-Methylthiopropionaldehyde is then converted to methionine by the Bucherer method, a modification of the Strecker method in which ammonium carbonate takes the place of ammonia. (Journal of Chemical Education, 2004)

**Fermentation Methods**

Although it is possible to prepare any natural amino acid by fermentation, a microbiological process, the special mutants that allow production to be done on a large scale have been developed only for the preparation of \((S)-\)lysine and \((S)-\)glutamic acid. The carbon sources for these syntheses are typically cane or beet molasses, raw sugar, or a starch hydrolysate. Ammonia is the source of nitrogen, and oxygen is provided by passing compressed air into the fermenting mixture.

An early fermentation process for the production of lysine made use of a pair of *E. coli* mutants. Normal *E. coli* can synthesize its own lysine from carbohydrates and ammonia, but the first mutant lacked the \(\alpha,\varepsilon\)-diaminopimelic decarboxylase that normally converts \(\alpha,\varepsilon\)-diaminopimelic acid (DAP) to lysine.

After the concentration of DAP had reached a maximum in the presence of the first mutant, the first mutant was removed and another *E. coli* strain was added. This second mutant produced DAP decarboxylase, but lacked lysine decarboxylase, thus allowing lysine to accumulate.
A second method for the production of lysine is a single stage fermentation process, now generally used for the microbial synthesis of lysine. This process makes use of a mutant of *Corynebacterium glutamicum* in which feedback mechanisms of product inhibition are overcome. Molasses is the most common carbon source, and this contains sufficient biotin to provide the more than 30 µg/L needed to suppress the excretion of glutamic acid. (Journal of Chemical Education, 2004)

All amino acids may be produced by fermentation. Whether they will or not depends on the costs of competing technologies such as chemical synthesis or extraction from protein sources. (holisticmed.net, 2003)

The fermentation method has the advantage of mass production at low cost, which was the great impetus for expanding the amino acid market. The manufacturing method of glutamate shifted from the extraction method to the fermentation method in the 1960s. Subsequently, a similar shift to the fermentation method took place for the other amino acids in rapid succession. (Ajinomoto, 2011)

**Enzymatic Synthesis of Amino Acids**

In the fourth method for synthesis of amino acids, the enzymatic procedures, pure enzymes are used, rather than the enzyme systems of living microorganisms, as in the fermentation methods.

At one time, for example, (S)-aspartic acid was produced mainly by the enantioselective, enzyme-catalyzed, addition of ammonia to fumaric acid, a substance that could be supplied in large quantities and at low cost.

Since only the naturally occurring isomer of aspartic acid was formed, resolution was not necessary. This method has since been supplanted by a continuous microbiological process in which the reacting solution passes over a fixed bed of an immobilized microorganism. (Journal of Chemical Education, 2004)

Choosing between processes depends on available technology, costs of raw material, market prices and sizes, cost of running fermentation versus synthesis reactions, and the environmental impact of the process itself. (holisticmed.net)
### SOURCES OF SIGNIFICANT PRODUCTION

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Chemical Extraction</th>
<th>Enzyme Synthesis</th>
<th>Fermentation</th>
<th>Catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cystine</td>
<td></td>
<td>Y</td>
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<td>Y</td>
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<tr>
<td>Histidine</td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Isoleucine</td>
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<tr>
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<tr>
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<tr>
<td>Valine</td>
<td>Y</td>
<td></td>
<td>Y</td>
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</tbody>
</table>

Source: Journal of Chemical Education, 2004

### Synthesis of Amino Acids

*Note: The following information was produced by Timothy Paustian, of the University of Wisconsin-Madison*

The amino acids synthesis pathways can be grouped into several logical units. These units reflect either common mechanisms or the use of common enzymes that synthesize more than one amino acid. These categories are: simple reactions, branch chain amino acids, aromatic amino acids, threonine/lysine, serine/glycine, and unique pathways. The aromatic amino acids, threonine/lysine and serine/glycine pathways have a common beginning and then diverge to form the amino acid of interest. Notice that each pathway begins with a central metabolite or something derived from "central metabolism". Using common compounds instead of synthesizing them from scratch saves energy and conserves genes since fewer enzymes are needed to code for the pathways.

#### Simple Reactions

*glutamine, glutamate, aspartate, asparagine and alanine*

In most cases these amino acids can be synthesize by one step reactions from central metabolites. They are simple in structure and their synthesis is also straight forward. Glutamate can by synthesized by the addition of ammonia to \( \alpha \)-ketoglutarate.
Figure 1 - The synthesis of glutamate

Glutamine is made by the addition of another ammonia molecule to glutamate.

Figure 2 - Synthesis of glutamine

The rest of the simple reactions involve transfer of the amino group (transamination) from glutamate or glutamine to a central metabolite to make the required amino acid. Aspartate is synthesized by the transfer of an ammonia group from glutamate to oxaloacetate.

Figure 3 - The synthesis of aspartate

Asparagine is made either by transamination from glutamine or by adding ammonia directly to aspartate.

or
Alanine synthesis is a bit of a mystery. Several reactions have been identified, but it has been impossible to generate an alanine auxotroph and therefore positively identify a required pathway. There are several pathways and the most likely is formation of alanine by transamination from glutamate onto pyruvate. A transamination using valine instead of glutamate is also possible.

Figure 5 - Synthesis of alanine

**Threonine/lysine**

Synthesis of threonine and lysine begins by the conversion of oxaloacetate to aspartate semialdehyde. This shared pathway costs one ATP and two NADPH + H⁺. Threonine biosynthesis is completed in three steps. First a second reduction with NADPH + H⁺, yields homoserine. This is phosphorylated to homoserine phosphate by ATP and finally converted into threonine.
The synthesis of lysine has been found to consist of different reactions in different bacterial species. A somewhat generalize pathway is presented. Lysine synthesis involves the addition of pyruvate to aspartate semialdehyde, the use of a CoA intermediate (either acetyl CoA or succinyl-CoA) and the addition of an amino group from glutamate. The group added from CoA (either succinyl or acetyl) serves as a blocking group, protecting the amino group from attack during transamination by glutamate. NADPH $+ H^+$ is required for reduction in the second step of the pathway.

**leucine, isoleucine and valine**

Examination of the isoleucine pathway versus the valine pathway demonstrates that the only difference is the substitution of an ethyl group instead of a methyl group to the $\alpha$-carbon of the intermediates. The intermediates are so similar that common enzymes catalyze four steps of each pathway. Isoleucine synthesis begins with threonine, which is deaminated to $\alpha$-ketobutyrate. From here the 4 step synthesis costs one NADPH $+ H^+$ per amino acid synthesized.
Figure 7 - Synthesis of valine and isoleucine.

Leucine biosynthesis starts off with the last intermediate in the valine synthesis, $\alpha$-ketoisovalerate. In the first step Acetyl-CoA is used to add an acetyl group to the molecule. Electrons are transferred to NAD$^+$ (note these can be used for other cellular processes) and one carbon is lost in the form of CO$_2$ at the fourth step of the pathway. In the final step, the amine from glutamate is added to $\alpha$-ketoisocaproatato form leucine.

Figure 8 - Synthesis of leucine
tryptophan, phenylalanine and tyrosine

Synthesis of the aromatic amino acids begins with the synthesis of chorismate - an important intermediate for many biosynthetic pathways. Phosphoenol pyruvate and erythrose 4-phosphate serve as beginning substrates for the pathway. A price of one NADPH + H\(^+\) and one ATP is exacted for every chorismate formed. In the sixth step of the synthesis another phosphoenol pyruvate molecule is added to the growing molecule.

Phenylalanine

Chorismate is converted to phenylpyruvate in two steps and phenylalanine is synthesized by a transamination reaction with glutamate. No energy is required to run these reactions.
Tyrosine

The synthesis of tyrosine is very similar to the synthesis of phenylalanine, but the reactions are carried out by different enzymes under different regulatory control. NADH is created in the formation of 4-hydroxyphenylpyruvate. Tyrosine is made by a similar transamination reaction as that seen in phenylalanine synthesis.

Tryptophan

Tryptophan synthesis is complex and involves 5 steps from chorismate. Glutamate donates an amine group in the first step of the pathway and pyruvate is lost from chorismate. In the next three steps a ribose sugar is added, this eventually contributes to the 5 membered ring of tryptophan. Energy is contributed to the process in the form of hydrolysis of pyrophosphate. This hydrolysis helps drive the addition of the ribose sugar in the second step of the reaction. In the last step of the pathway serine serves as the donor of the α carbon amino group of tryptophan.
**Unique pathways**

**cysteine, methionine, histidine and arginine**

These pathways involve something unusual, either the structure of the amino acid is different enough than the other common amino acids, or sulfur is involved in their synthesis. In any case, unique enzymes are involved in every step of the way. Here we just examine what they start with and how much it costs the cell.

**Cysteine**

Synthesis of cysteine is a two step reaction. Serine and acetyl-CoA combine to form O-acetylserine. Sulfide from sulfur assimilation is then added to O-acetylserine to form cysteine. The pathway for cysteine synthesis was covered in sulfate assimilation.

**Methionine**

Methionine is synthesized from oxaloacetate. Succinyl-CoA participates and cysteine donates a sulfur group to the molecule. Oxaloacetate is first converted into homoserine as described above in the threonine biosynthetic pathway. Homoserine then has a sulfur attached to the end in two steps and finally methionine is formed by the addition of a methyl group.

![Figure 13 - Synthesis of methionine. The donor of the methyl group (R) is a methyl carrier in the cell, N⁵,N¹⁰-Methylene terahydropteroyl.](image)

**Histidine**

The synthesis of histidine is long and complex and its pathway is intertwined with nucleic acid biosynthesis (specifically purine). The pathway seems to be universal in all organisms able to synthesize histidine. The first five steps of the pathway take ribose from phosphoribosyl pyrophosphate (PRPP) and transform it into Imidazoleglycerol phosphate. Once the imidazole ring is formed, glutamate donates the α-amino group and the newly formed amine is oxidized to histidine in the last step of the pathway. Energy is required in the form of ATP (in this case elements of the ATP molecule actually becomes part of the amino acid) and pyrophosphate which is lost from phosphoribosyl pyrophosphate and ATP help drive the reaction.
Investigations into histidine biosynthesis have yielded many insights into microbial metabolism that have contributed greatly to our understanding of how cells function at the genetic and biochemical level. Work in this area is still yielding important results.

**Arginine**

Synthesis of arginine is an eight step process starting with the amino acid glutamate. Two ATP and one NADPH + H⁺ are utilized to synthesize each arginine.
Taurine

Taurine was first isolated from ox bile in 1827 by German scientists Fredrich Tiedemann and Leopold Gmelin. The name, taurine, is a derivative of the Latin term, taurus.

Taurine occurs naturally in food, especially in seafood and meat, and it is a normal metabolite in humans. It is a metabolic product of sulphur-containing amino acids, and it is mainly biosynthesized from cysteine in the liver (SCF, 1999).

Today, a small amount taurine is still derived from bovine and ovine sources. This natural taurine, however, is essentially a by-product from the production of cholic acid, deoxycholic acid and other bile acids, and is therefore available in extremely limited supplies. New Zealand Pharmaceuticals, Ltd., for example, produces 800 tons of bile acids each year from oxen, cattle and sheep bile. Of that amount, only 20 tons consists of taurine for all markets.

Most taurine today is synthesized from methionine, Vitamin E and cysteine.
Commercial Suppliers:

Many companies commercially supply required amino acids as ingredients for livestock feed and pet food. Major suppliers include—but are not limited to—the following companies:

Ajinomoto Heartland LLC
8430 West Bryn Mawr Avenue,
Suite 650, Chicago, IL 60631-3421
Tel: +1 (773) 380-7000
Fax: +1 (773) 380-7006

Changshu Yudong Chemical Company
Wangshi Haiyu Town
Changshu City
Jungshu Province, China PC 215519
Tel +86-512-52565808
Fax +86-512-52561808
E-mail: yonglida@public1.sz.js.cn
Website: www.yudongchem.com

Qianjiang Yongan Pharmaceutical Co., LTD
No. 16 Zhuze Road
Qianjiang, China
Tel: +8 6-728-6202727/6201636
Fax: +86-728-6202797
E-mail: yasales@chinataurine.com
Website: www.chinataurine.com

Changshu Yudong Chemical Company
Wangshi Haiyu Town
Changshu City
Jungshu Province, China PC 215519
Tel +86-512-52565808
Fax +86-512-52561808
E-mail: yonglida@public1.sz.js.cn
Website: www.yudongchem.com

Zone Industrielle Grasbesch
L-3370 Leudelange
G.D. de Lussembour
Tel: +352-49-89-770
Fax: +352-49-89-771
Email: sales@taurinepffg.com
Website: www.taurinepffg.com
6. A summary of any available previous reviews by State or private certification programs or other organizations of the petitioned substance

These required amino acids not been previously petitioned, but has been allowed for use in pet food products certified as “organic”, or” made with organic,” since October 2002.

Following the 2004 directive by NOP that pet food products could be certified under 7 CFR § 205.605 and §205.606, certifiers have relied upon the guidance from the NOP regarding the use of taurine and other required nutrients for pet food products. In November 2006, the NOP issued a notice in response to a complaint, reading, in part:

“The complaint that resulted in the opening of this case questioned the use of the nutrients docosahexenoic acid (DHA) and arachidonic acid (ARA) in an organic (redacted). The resulting investigation led to questions concerning the use of the nutrients, nucleotides and taurine. FDA permits the use of all four in (redacted). Accordingly, provided the nutrients in question are in full compliance with FDA rules and regulations, they would comply with the NOP National List as currently written.” (underline added)

The 2006 notice established a basis for including amino acids (sometimes referred to as “accessory nutrients” in human food) under the materials allowed to be included in certified organic food under §205.605(b) “Nutrient vitamins and minerals, in accordance with 21 CFR 104.20, Nutritional Quality Guidelines For Foods.” Certifiers relied upon this guidance as approval for allowing the use of required nutrients in pet food products certified as “organic” and “made with organic.”

In early 2010, the USDA National Organic Program issued a memorandum to certifiers specifying that 21 CFR 104.20 covered only vitamins and minerals, and thus could not be utilized as justification for including amino acids and other nutrients in certified organic food products. The NOP has subsequently issued a directive outlining a transition period for enforcement of the new interpretation.

In addition, the NOSB in November 2008 unanimously adopted a recommendation regarding changes in the organic regulations to support labeling of organic pet food. The NOP is currently developing proposed regulations based upon the 2008 NOSB recommendation. As recommended by the NOSB, §205.603 would be amended to
include the synthetic substances allowed for use in organic pet food. §205.603 already includes allowances for the inclusion of vitamins and trace minerals in certified organic livestock production.

7. Information regarding EPA, FDA, and State regulatory authority registrations, including registration numbers

U.S. Environmental Protection Agency (EPA)

The U.S. Environmental Protection Agency does not regulate amino acids, so these materials are not listed on the EPA List 4 list of inert pesticide ingredients.

U.S. Food and Drug Administration (FDA)

The federal regulations, enforced by the United States Food and Drug Administration (FDA), establish standards applicable for all animal feeds: proper identification of product, net quantity statement, manufacturer's name and address, and proper listing of ingredients. (FDA, 2010)

The regulatory role of the U.S. Food and Drug Administration in the area of required amino acids was addressed in a June 27, 2011 letter from FDA’s Center for Veterinary Medicine to the Standards Division of the USDA National Organic Program. In that letter, CVM states: “The Center for Veterinary Medicine (CVM) is the Center within FDA that has regulatory authority over animal feeds and the ingredients used to formulate animal feed products. For animal feeds, including foods for dogs and cats, the CVM has not established or promulgated any minimum requirements (MR), adequate intakes (AI), recommended allowances (RA) or other reference standards for daily nutrient intakes for any particular nutrient. The CVM relies on the various ad hoc expert nutrition committees under the Committee on Animal Nutrition of the National Research Council in the National Academy of Sciences for establishment of which nutrients, and in what amounts, are essential in the diets for specific species of domestic animals to meet that species' daily nutrient requirements. For dogs and cats, the required essential nutrients are listed and described in the 2006 edition of Nutrient Requirements of Dogs and Cats. The CVM considers the nutrients listed in Tables 15-3, 15-5, 15-8, for dogs, and Tables 15-10, 15-12, 15-14 for cats, to be essential nutrients and eligible for supplementation if required to meet and provide the listed MR, or in the absence of a stated value for the MR then the listed value for AI for that nutrient, in products represented to be "complete and balanced."

State Regulatory Authority

Most states also enforce their own labeling regulations under their state feed laws. States commonly adopt model pet food regulations established by the Association of American Feed Control Officials (AAFCO). These regulations are more specific in nature, covering aspects of labeling such as the product name, the guaranteed analysis, the nutritional adequacy statement, feeding directions, and calorie statements. (FDA, 2010). Within the pet food industry, the Dog and Cat Food Nutrient Profiles listed in the Official Publication of AAFCO is widely recognized as the definitive source of information regarding nutritional adequacy in pet food products.
As explained in the FDA CVM June 27, 2011 letter, however, the FDA relies upon the Committee on Animal Nutrition of the National Research Council as the definitive source of information regarding the nutritional requirements of dogs and cats:

“The AAFCO Dog and Cat Food Nutrient Profiles do not contain any nutrient that has not been determined to be essential and listed in the previously referenced tables in the 2006 edition of Nutrient Requirements of Dogs and Cats. The 2006 edition of Nutrient Requirements of Dogs and Cats contains some additional specific fatty acids as essential required nutrients for specific life stages of dogs and cats that are not currently listed in the AAFCO Dog and Cat Food Nutrient Profiles. The AAFCO Dog and Cat Food Nutrient Profiles are presently under consideration for revision, but what the specific revisions will be cannot be stated at this time. As previously indicated, FDA CVM relies on the Committee on Animal Nutrition of the National Research Council in the National Academy of Sciences for establishment of which nutrients are essential in the diets of animals, not the AAFCO Dog and Cat Food Nutrient Profiles.”

The required amino acids are recognized as GRAS under the following sections of 21 CFR

- Arginine §582.5145
- Methionine §582.5475
- Cysteine §582.5271
- Lysine §582.5411
- Taurine §573.980
- Tryptophan §582.5915
- Threonine §582.5881
- Histidine §582.5361
- Isoleucine §582.5381
- Leucine §582.5406
- Phenylalanine §582.5590
- Tyrosine §582.5920
- Valine §582.5925

All amino acids referenced in 21 CFR §582, except Methionine and Cysteine, are declared GRAS for both the L- and DL- form. For methionine, §582.5475 makes no reference to L- or DL form. Cysteine is declared GRAS for L- form only.

U.S. Department of Agriculture (USDA)

Amino acids in animal feed are not specifically regulated by the U.S. Department of Agriculture.

Clean Air Act
These required amino acids to not contain any hazardous air pollutants. These amino acids to not contain any Class 1 Ozone depletors, nor do they contain any Class 2 Ozone depletors.

**Clean Water Act**

These amino acids are not listed as Hazardous Substances under the CWA, nor is it listed as Priority or Toxic Pollutants under the CWA.

**OSHA**

These amino acids are not considered highly hazardous by OSHA.

8. The Chemical Abstract Service (CAS) number or other product numbers of the substance and labels of products that contains the petitioned substance

**Chemical Abstract Numbers**

<table>
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<tr>
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<th>L- CAS No.</th>
<th>DL- CAS No.</th>
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<td>Methionine</td>
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**Labels of Products**

Attachment A contains actual ingredient labels from current conventional and certified “Made with Organic” products in the marketplace.

9. The substance's physical properties and chemical mode of action
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<th>Molecular Formula</th>
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<td>119.12 g/mol</td>
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<td>DL- 516-06-3</td>
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</table>

### Characteristics

With the exception of proline, all amino acids present in most proteins are α-amino acids and have α-amino and α-carboxyl groups, both of which are involved in the peptide bonds that are essential for protein structure.

### Chemical Mode of Action

Each amino acid has a side chain on the α-carbon that ranges in size from a hydrogen atom to an indole ring. The various side chains contribute to the secondary and tertiary structure of protein, and several are often conjugated to various other groups, such as phosphate and amino sugars. Also of nutritional importance are the acidic and basic side chains in proteins that can accept or donate protons, depending on the pH of the medium in which the protein is present. Acid-precipitated proteins (e.g., casein) have protons added to the carboxyl group side chains. These protons, together with those on the basic side chains, are released during digestion, absorption, and utilization and contribute to
metabolic acido-sis. Amino acids are important in providing building blocks for many important biologically active compounds plus countless peptides and proteins.

**Chemical interactions with other substances, especially substances used in organic production**

There is no evidence of negative interaction with substances used in organic production.

**Toxicity and environmental persistence**

In humans, symptoms of amino acid toxicity are damage to kidneys. Consuming large amounts of amino acids, increases the levels of these compounds in the bloodstream. As a result, kidneys must filter high quantities of compounds out of the blood, which can cause kidney strain over time. An amino acid overdose can also have a negative effect on the liver. Amino acid metabolism releases ammonia, a toxic compound. Very high doses of amino acids can lead to a temporary buildup in ammonia in the liver, which can prove harmful.

Here is the specific toxicity information for the required amino acids encompassed in this petition:

**Arginine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.

**Chronic Effects on Humans:** MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells.

**Other Toxic Effects on Humans:** Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.

**Special Remarks on Toxicity to Animals:** Not available.

**Special Remarks on Chronic Effects on Humans:** May affect genetic material. Some Laboratory experiments have resulted in mutagenic effects. Although some dietary studies in animals have demonstrated that arginine deficiency can impair reproductive organ development as well as having adverse effects on gestation and lactation, we did not locate any literature on possible adverse reproductive effects of supplemental arginine during human pregnancy.

**Special Remarks on other Toxic Effects on Humans:** Acute Potential Health Effects: Skin: May cause skin irritation. Eyes: May cause eye irritation. Inhalation: May cause respiratory tract irritation. Ingestion: May cause gastrointestinal tract irritation. The toxicological properties of this substance have not been fully investigated.

**Methionine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.

**Chronic Effects on Humans:** Not available.
Other Toxic Effects on Humans: Hazardous in case of skin contact (irritant), of ingestion, of inhalation.
Special Remarks on Toxicity to Animals: Not available.
Special Remarks on Chronic Effects on Humans: Passes through the placental barrier in animal.

**Cysteine**

Toxicity to Animals: Acute oral toxicity (LD50): 660 mg/kg [Mouse].
Chronic Effects on Humans: The substance is toxic to lungs, mucous membranes.
Other Toxic Effects on Humans: Hazardous in case of skin contact (irritant), of ingestion, of inhalation. Slightly hazardous in case of skin contact (permeator).
Special Remarks on Toxicity to Animals: Not available.
Special Remarks on Chronic Effects on Humans: Not available.

**Lysine**

Toxicity to Animals: Acute oral toxicity (LD50): 10000 mg/kg [Rat].
Chronic Effects on Humans: Not available.
Other Toxic Effects on Humans: Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.
Special Remarks on Toxicity to Animals: Not available.
Special Remarks on Chronic Effects on Humans: Not available.

Special Remarks on other Toxic Effects on Humans:

Acute Potential Health Effects: Skin: May cause skin irritation. Eyes: May cause eye irritation. Inhalation: May cause respiratory tract irritation. Ingestion: May cause digestive tract irritation. The toxicological properties of this substance have not been fully investigated. May also affect behavior (somnolence,), metabolism.

**Taurine**

Toxicity to Animals: Acute oral toxicity (LD50): >5000 mg/kg [Rat].
Chronic Effects on Humans: Not available.
Other Toxic Effects on Humans: Slightly hazardous in case of skin contact (irritant), of ingestion, of inhalation.
Special Remarks on Toxicity to Animals: Not available.
Special Remarks on Chronic Effects on Humans:

May cause adverse reproductive effects and birth defects (teratogenic) based on animal test data. May affect genetic material (mutagenic)
Special Remarks on other Toxic Effects on Humans:

Acute Potential Health Effects: Skin: May cause skin irritation. Eyes: May cause eye irritation. Inhalation: May cause respiratory tract irritation. Ingestion: May cause digestive tract irritation. The toxicological properties of this substance have not been fully investigated. May also affect behavior (somnolence,), metabolism.
**Tryptophan**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.
**Chronic Effects on Humans:** Not available.
**Other Toxic Effects on Humans:** Hazardous in case of ingestion. Slightly hazardous in case of inhalation.
**Special Remarks on Toxicity to Animals:** Not available.
**Special Remarks on Chronic Effects on Humans:** Not available.

**Threonine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.
**Chronic Effects on Humans:** Not available.
**Other Toxic Effects on Humans:** Hazardous in case of ingestion. Slightly hazardous in case of inhalation. Slightly hazardous in case of skin contact (irritant).
**Special Remarks on Toxicity to Animals:** Not available.
**Special Remarks on Chronic Effects on Humans:** Passes through the placental barrier in human.

**Histidine**

**Toxicity to Animals:** Acute oral toxicity (LD50): 15000 mg/kg [Mouse].
**Chronic Effects on Humans:** The substance is toxic to lungs, mucous membranes.
**Other Toxic Effects on Humans:** Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant).
**Special Remarks on Toxicity to Animals:** Not available.
**Special Remarks on Chronic Effects on Humans:** Passes through the placental barrier in human.

**Isoleucine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.
**Chronic Effects on Humans:** Not available.
**Other Toxic Effects on Humans:** Very hazardous in case of ingestion. Hazardous in case of skin contact (irritant, permeator), of inhalation.
**Special Remarks on Toxicity to Animals:** Not available.
**Special Remarks on Chronic Effects on Humans:** Passes through the placental barrier in human.

**Leucine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.
**Chronic Effects on Humans:** Not available.
**Other Toxic Effects on Humans:** Extremely hazardous in case of inhalation. Very hazardous in case of ingestion.
**Special Remarks on Toxicity to Animals:** Not available.  
Special Remarks on Chronic Effects on Humans: Passes through the placental barrier in animal.

**Phenylalanine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.  
**Chronic Effects on Humans:** Not available.  
**Other Toxic Effects on Humans:** Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant).  
**Special Remarks on Toxicity to Animals:** Not available.  
**Special Remarks on Chronic Effects on Humans:** Not available.

**Tyrosine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.  
**Chronic Effects on Humans:** Not available.  
**Other Toxic Effects on Humans:** Hazardous in case of ingestion, of inhalation. Slightly hazardous in case of skin contact (irritant).  
**Special Remarks on Toxicity to Animals:** LD50 [Mouse] - Route: Intraperitoneal; Dose: >1450 mg/kg  
**Special Remarks on Chronic Effects on Humans:** May affect genetic material (mutagenic). May cause adverse reproductive effects and birth defects (teratogenic) based on animal test data. No human data has been found.  
**Special Remarks on other Toxic Effects on Humans:** Acute Potential Health Effects: Skin: May cause skin irritation Eyes: May cause eye irritation Inhalation: Dust may cause respiratory tract irritation. Ingestion: May cause digestive tract irritation. Ingestion of large (toxic) amounts may also affect the liver, cause corneal disease, keratitis, tachycardia and hypertension or bradycardia and hypotension. Chronic Potential Health Effects: Ingestion: Prolonged or repeated ingestion may affect the urinary system, blood, and behavior. Skin: Prolonged or repeated contact may cause dermatitis.

**Valine**

**Toxicity to Animals:** LD50: Not available. LC50: Not available.  
**Chronic Effects on Humans:** Not available.  
**Other Toxic Effects on Humans:** Hazardous in case of ingestion. Slightly hazardous in case of skin contact (irritant), of inhalation.  
**Special Remarks on Toxicity to Animals:** Not available.  
**Special Remarks on Chronic Effects on Humans:** Passes through the placental barrier in human.

**Environmental impacts from its use or manufacture;**

**Use:**
There is no evidence of negative environmental impact from the use of essential amino acids in pet food. Excess amino acids are excreted from pets—as in other mammals, as a component of nitrogen in urine. In cows, for example, free amino acids comprise 1.3 percent of the nitrogen component in urine. (Bristow, 1992)

Because most pet foods are complete and balanced, there should be minimal impact on the environment.

**Arginine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.
**Products of Biodegradation:** Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
**Toxicity of the Products of Biodegradation:** The product itself and its products of degradation are not toxic.

**Methionine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.
**Products of Biodegradation:** Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
**Toxicity of the Products of Biodegradation:** The products of degradation are more toxic.

**Cysteine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.
**Products of Biodegradation:** Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
**Toxicity of the Products of Biodegradation:** The products of degradation are more toxic.

**Lysine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.
**Products of Biodegradation:** Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

**Taurine**

Ecotoxicity: Not available.
BOD5 and COD: Not available.
Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

**Tryptophan**

Ecotoxicity: Not available.
BOD5 and COD: Not available.
Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

**Threonine**

Ecotoxicity: Not available.
BOD5 and COD: Not available.
Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

**Histidine**

Ecotoxicity: Not available.
BOD5 and COD: Not available.
Products of Biodegradation: Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

**Isoleucine**
**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.

**Products of Biodegradation:**
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

**Toxicity of the Products of Biodegradation:** The products of degradation are more toxic.

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**Leucine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.

**Products of Biodegradation:**
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

**Toxicity of the Products of Biodegradation:** The products of degradation are more toxic.

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**Phenylalanine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.

**Products of Biodegradation:**
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

**Toxicity of the Products of Biodegradation:** The products of degradation are more toxic.

---

**Tyrosine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.

**Products of Biodegradation:**
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.

**Toxicity of the Products of Biodegradation:** The product itself and its products of degradation are not toxic.

---

**Valine**

**Ecotoxicity:** Not available.
**BOD5 and COD:** Not available.

**Products of Biodegradation:**
Possibly hazardous short term degradation products are not likely. However, long term degradation products may arise.
Toxicity of the Products of Biodegradation: The products of degradation are more toxic.

Manufacture

As mentioned in Section 5, amino acids are typically synthesized through one of four processes:
Extraction from natural sources;
Chemical synthesis
Fermentation; and
Enzymatic synthesis.

Effects on human health

As in dogs and cats, amino acids are an important part of the human nutritional intake.

Amino acids are critical to life, and have many functions in metabolism. One particularly important function is to serve as the building blocks of proteins, which are linear chains of amino acids. Amino acids can be linked together in varying sequences to form a vast variety of proteins. Twenty-two amino acids are naturally incorporated into polypeptides and are called proteinogenic or standard amino acids. Of these, 20 are encoded by the universal genetic code. Nine standard amino acids are called "essential" for humans because they cannot be created from other compounds by the human body, and so must be taken in as food.

Amino acids in human food are regulated under 21 CFR §172.

Amino acid toxicity is rare, and protein restriction for patients with renal or liver failure is obsolete because this only aggravated malnutrition. A true example of protein toxicity consists of gastrointestinal hemorrhage that precipitates hepatic encephalopathy in liver insufficiency, most likely because hemoglobin is an unbalanced protein because it lacks the essential amino acid isoleucine. (Soeters, 2004)

Studies have shown that excessive intake of some amino acids may lead to some disturbances. Both the age of the subject, and the adequacy of the diet with respect to protein, caloric intake, vitamins, as well as the relative proportion of amino acids in the diet influence the individual’s susceptibility to the amino acid load. (Deshpande, 2002). However, this is not a relevant concern, given that these materials are not intended for human consumption in this petitioned use.

Effects on soil organisms, crops or livestock

Soil Organisms
Amino acids are commonly produced from microorganisms found in natural soil. One gram of natural soil contains about 100 million microorganisms. From these a useful one can be picked out.

Generally, microorganisms produce the 20 kinds of amino acids only in the amounts necessary to themselves. They have a mechanism for regulating the quantities and qualities of enzymes to yield amino acids only in the needed amounts. Therefore, it is necessary to release this regulatory mechanism in order to manufacture the target amino acid in large amounts.

**Crops or Livestock**

Chains of carbon, with each carbon atom linked to other carbons, form the “backbone” of organic molecules. These carbon chains, with varying amounts of attached oxygen, H, N, P and S, are the basis for both simple sugars and amino acids and more complicated molecules of long carbon chains or rings. Depending on their chemical structure, decomposition is rapid (sugars, starches and proteins), slow (cellulose, fats, waxes and resins) or very slow (lignin). (UN FAO 1998)

Many plants, including important agricultural crops, form symbioses with soil microorganisms that take N2 gas out of the atmosphere and convert it to forms that are useful for growth (called N fixation). In some cases, plants will take up simple amino acids from soil. Organic nitrogen actually exists in many forms in soil, including as free amino acids, and can be bound in large organic molecules that are associated with soil minerals. (Penn State, 2011)

The amino acids contained in this petitions are either required or recommended to adequate livestock nutrition.

**10. Safety information about the substance**

**Material Safety Data Sheets**

Attachment A includes Material Safety Data Sheets for all of the petitions amino acids in this category.

**Substance Report from the National Institute of Environmental Health Studies**

The Food and Drug Administration (FDA) does not require a National Institute of Environmental Health Studies report for taurine. Therefore a NIEHS report has not been developed. The information contained in this petition under Section 9 covers the safety of human health and environment.
11. Research information about the substance which includes comprehensive substance research reviews and research bibliographies, including reviews and bibliographies which present contrasting positions to those presented by the petitioner in supporting the substance’s inclusion on or removal from the National List.

The National Research Council’s *Nutrient Requirements of Dogs and Cats* (2006) stands as the primary source of scientific information regarding the amino acid requirements for dogs and cats. The 2006 publication was developed by an ad hoc committee convened by the NRC Committee on Animal Nutrition in 2000.

As explained in the preface of the 2006 publication “Throughout the study process, the (ad hoc) committee sought input from various sources. We held public meetings in conjunction with professional meetings and invited experts to speak with us as we completed our task. Over the course of 3 years, the committee held six meetings and four public sessions. We acquired data and information from various public and private organizations. By combining a thorough literature review with critical analysis of scientific data and professional experiences, the committee developed recommendations that are firmly founded in science. (NRC, 2006)”

12. Petition Justification Statement

Overview

The U.S. Department of Agriculture’s National Organic Standards recognized from the outset that vitamins, minerals and other required nutrients are essential in formulating certified organic products that will meet the nutritional requirements of humans and animals.

Specifically, §205.603(d)(2) and §205.603(d)(3) allow trace minerals and vitamins to be utilized in livestock for enrichment or fortification when FDA approved. Similarly, §205.605(b) allows food products labeled as “organic” or “made with organic” to contain nutrient vitamins and minerals, in accordance with 21 CFR 104.20, Nutritional Guidelines for Foods. Those nutrients are allowed for use in livestock feed and human food regardless of the method of manufacturing or handling.

Under the current regulations, pet food products seeking certification under the USDA Organic Standards must be produced in accordance with §205.605 and §205.606 of the National Organic Standards. Certain nutrients required by cats and/or dogs are not included in §205.605, §205.606, and are not referenced in 21 CFR 104.20(b). Without the inclusion of those nutrients, however, commercially-produced pet foods cannot be labeled as *Complete and Balanced* under the model regulations developed by the
Association of American Food Control Officials in accordance with the National Research Council’s *Nutritive Requirements of Cats and Dogs*.

The specific levels of required and recommended nutrients (including amino acids) are listed in the following tables of the National Research Council’s *Nutritive Requirements of Cats and Dogs*.

Table 15-3 Nutrient Requirements for Growth of Puppies after Weaning  
Table 15-5 Nutrient Requirements for Adult Dogs for Maintenance  
Table 15-8 Nutrient Requirements for Bitches for Late Gestation and Peak Lactation  
Table 15-10 Nutrient Requirements for Growth of Kittens after Weaning  
Table 15-12 Nutrient Requirements for Adult Cats for Maintenance  
Table 15-14 Nutrient Requirements for Queens for Late Gestation and Peak Lactation

The tables referenced above are all included with this petition as Attachment D.

It is important to note that the NRC is recognized as the authoritative source of nutrient information within the international community. For example, The European Pet Food Industry Federation’s August 2011 report entitled Nutritional Guidelines for Complete and Complementary Pet Food for Cats and Dogs, contains the following table:

![Table A4 - Substantiation of nutrient recommendations for dogs](image)

(European Pet Food Industry Federation, 2011)

State regulators utilize the model regulations in the Official Publication of AAFCO as the basis of determining if a commercial pet food product qualifies to be labeled as complete and balanced. The specific levels of required amino acids identified in the Official Publication of AAFCO are listed on Pages 7-9 of this petition.

Other references on this topic include:

*Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations*, James Morris, Department of Molecular Biosciences, School of Veterinary Medicine, University of California, Davis. *Nutrition Research Reviews*, 2002, 15 Pages 153-168.
Why the synthetic substance is necessary for the production of an organic product.

Because dogs and cats rely on commercially-prepared foods as their sole source of nutrition, it is vital that those commercial food products contain all of the nutrients required for healthy growth and adult maintenance. Accordingly, the American Association of Feed Control Officials (AAFCO) have developed model regulations, based upon the National Research council’s *Nutrient Requirements of Dogs and Cats*, regarding the level of nutrients for a commercially-produced pet food to be labeled as complete and balanced. The term complete and balanced means that the formula supplies a nutritionally adequate diet when fed according to label instructions.

Deficiency of even one of the essential amino acids can have damaging—and even fatal—effects on the animal. Within the order Carnivora, cats are more sensitive than dogs and ferrets to hyperammonaemia resulting from consumption of an arginine-free diet. Cats are exquisitely sensitive to arginine deficiency, for there is no other example in a mammalian species where consumption of a single meal lacking an essential nutrient can lead to death. (Morris, 2002)

Nonsynthetic substances or alternative cultural methods that could be used in place of the petitioned synthetic substance

Dogs and cats have been domesticated over the past thousands of years, but their digestive tract remains largely unchanged from the time when they acted as predators in the wild. Consequently, their protein (amino acid) requirements remain largely unchanged from the time when the animals consumed diets consisting of freshly-killed animals. This historic diet included more than simply the muscle meat of the prey, and included the hide, fur, bones, --and for dogs--the contents of the stomach.

Consequently a diet consisting exclusively of fresh-killed game (for cats), and a combination of fresh killed game and plant matter (for dogs), could contain the levels of amino acids required for growth and maintenance in dogs and cats. Evidence shows that animals existing in the wild do not have as long of a lifespan as those consuming complete and balanced pet food.

Replicating the nutrient levels contained in a diet of freshly-killed game and foraged plant matter (for dogs) is extremely difficult in a commercially-manufactured food.
product. For example, the heat required during processing to meet the food safety requirements for commercially manufactured food products also decreases the bioavailability of several endogenous amino acids—particularly taurine (Zoran, 2002). Accordingly, additional incremental amounts of these nutrients must be added to commercially manufactured products.

Further, even though cats do not have the ability to synthesize these amino acids, the amino acids are not conserved. In fact, utilization of taurine, arginine, methionine and cysteine is higher in cats than in dogs. (Zoran, 2002)

Not all of the required amino acids will require the use of synthetic materials. As mentioned above, amino acids are derives from many animal and plant sources. The following table lists the dietary sources of the amino acids:

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Dietary Sources - Animal</th>
<th>Dietary Sources - Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>cottage cheese, beef, pork, poultry, wild game, seafood</td>
<td>wheat germ, flour, buckwheat, oatmeal, peanuts, nuts, seeds (pumpkin, sesame, sunflower), chick peas, soybeans</td>
</tr>
<tr>
<td>Methionine</td>
<td>eggs, fish, meats</td>
<td>Cereal grains, Seeds (sesame, pumpkin), nuts</td>
</tr>
<tr>
<td>Cysteine</td>
<td>Cottage cheese, eggs, pork, poultry (chicken, turkey, duck), yogurt</td>
<td>garlic, broccoli, Brussels sprout, oats, red peppers, wheat germ, sprouted lentils</td>
</tr>
<tr>
<td>Lysine</td>
<td>Beef, cheese, eggs, fish, milk, poultry</td>
<td>Amaranth, beans (kidney, Navy) Soybean, lentils,</td>
</tr>
<tr>
<td>Taurine</td>
<td>Meat, seafood</td>
<td></td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Beef, eggs, fish, lamb, pork, poultry (chicken, turkey), spirulina</td>
<td>Bananas, nuts (almond, pistachio, cashew), potatoes, seeds (pumpkin, sesame), soybeans</td>
</tr>
<tr>
<td>Threonine</td>
<td>cottage cheese, poultry, fish, meat,</td>
<td>Lentils</td>
</tr>
<tr>
<td>Histidine</td>
<td>Cheese, eggs, meat, poultry, pork</td>
<td>Brewer’s yeast, rice, rye, wheat</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>Cheese, eggs, fish, lamb, poultry (chicken, turkey)</td>
<td>soy protein, seaweed</td>
</tr>
<tr>
<td>Leucine</td>
<td>beef, fish, , chicken, eggs,</td>
<td>Almonds, beans, chickpea, corn, oats, peanuts, rice, soybeans,</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Beef, cheese, fish, poultry, pork, yogurt</td>
<td>Nuts, seeds, soy products</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>cheese, cottage cheese, fish, poultry (chicken, turkey), yogurt,</td>
<td>Almonds, lima beans, peanuts, seeds (pumpkin, sesame) soy products,</td>
</tr>
<tr>
<td>Valine</td>
<td>cottage cheese, fish, poultry</td>
<td>Peanuts, sesame seeds, and lentils</td>
</tr>
</tbody>
</table>

(WHO, 2007, Virginia-Maryland Regional Veterinary College, 2010)

The following required amino acids are generally available through organically-produced dietary sources:

- Histidine
- Isoleucine
- Leucine
• Phenylalanine-tyrosine
• Valine

As noted by the NOSB in its November 2008 recommendation regarding Certified Organic Pet Food, the following amino acids are not generally available from organically produced agricultural products, and must be added in a synthetic format:

• l-arginine
• d-l Methionine
• l-cysteine
• l-lysine
• Taurine
• l-tryptophan
• l-threonine

Because of the specific minimum (and in some cases, maximum) level of these essential nutrients that must be present in a formulated food product to be recognized as complete and balanced, small amounts of the synthetic materials are used to balance the formulations, and to compensate for the loss that occurs through the normal manufacturing process.

**Beneficial effects to the environment, human health (pet health), or farm ecosystem from use of the synthetic substance that support the use of it instead of the use of a nonsynthetic substance or alternative cultural methods.**

**Effect on the Environment**

These required amino acids allows for the formulation of pet foods with the correct balance of these amino acids for the diet of cats and dogs. While most attention is dedicated to minimum requirements, excess levels of certain required nutrients can create an imbalance that can be detrimental to the pet, and results in higher levels of amino acids being excreted by the animal. As stated above, excess amino acids are excreted as a component of nitrogen in the urine of these animals. Formulation of pet food products with the appropriate levels of required amino acids will reduce the amount of excess amino acids excreted by the animal.

**Effect on Human (and Animal) Health**

The essentiality of these amino acids comprises the foundation of this petition for their addition to §205.603 of the National List.

As explained in the NRC, “Dietary protein is required for two reasons. First, protein provides amino acids that dogs and cats cannot synthesize (essential amino acids) but are required for synthesis of the many proteins in the body. Second, protein provides dispensable amino acids (amino acids that can be synthesized if appropriate nitrogen and carbon
sources are provided) that animals need for maintenance, growth, gestation, and lactation. Dispensable amino acids provide nitrogen and carbon for the synthesis of any needed dispensable amino acid and carbon for gluconeogenesis and/or energy. Dispensable amino acids also provide nitrogen and/or structural components necessary to make other compounds that are essential for life, such as purines, pyrimidines, heme, various hormones, neurotransmitters, and/or neuromodulators (e.g., thyroxine, catecholamines, y-aminobutyric acid, taurine).

“For either dogs or cats that consume primarily animal tissue, amino acids also provide carbon chains for gluconeogenesis to supply glucose to tissues that require it (e.g., red blood cells, nervous tissue) to maintain normal tissue metabolism. As for most other animals, the following 10 amino acids have been shown to be essential for both dogs and cats: arginine (Arg), histidine (His), isoleucine (He), leucine (Leu), lysine (Lys), methionine (Met), phenylalanine (Phe), threonine (Thr), tryptophan (Trp), and valine (Val). In omnivores and certain herbivores (e.g., rats, chicks), removal of a single essential amino acid results in a decrease in food intake that is known to be a primary neuroresponse caused by the lack of the limiting essential amino acid (Gietzen, 1993). In cats, the limited work available (e.g., Hardy et al., 1977; Rogers and Morris, 1979) shows that food intake does not decrease as quickly as in rats after initial consumption of diet devoid of an essential amino acid. Although food intake does decrease with time, the depression is not as severe as in omnivores and herbivores. (NRC, 2006)”

The negative interactions among amino acids have, for the most part, not been studied in humans. (Baker, 2008)

**References for Justification Statement**


http://www.holisticmed.net/aspartame/aminoacid.pdf

FDA (2010) Pet Food Labels – General, Center for Veterinary Medicine, March


Morris, James (2002) Idiosyncratic nutrient requirements of cats appear to be diet-induced evolutionary adaptations. Department of Molecular Biosciences, School of Veterinary Medicine, University of California, Davis. Nutrition Research Reviews, 15 Pages 153-168. 
http://journals.cambridge.org/download.php?file=%2FNRR%2FNRR15_01%2FS0954422402000070a.pdf&code=395e67a2405fe3e7ef0a6e06d5ccf9fa

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Penn State (2011) The N Cycle, Crops and Soil Sciences, State College, PA 
http://cropsoil.psu.edu/research/kaye-lab/lab-logo


UN FAO (1998) Organic matter decomposition and the soil food web 
http://www.fao.org/docrep/009/a0100e/a0100e05.htm

http://whqlibdoc.who.int/trs/WHO_TRS_935_eng.pdf


13. Commercial Confidential Information Statement

There is no confidential Business Information being submitted with this petition.
Attachment A

Current Ingredient Labels of Conventional And Made with Organic Products Containing the Petitioned Materials

Below are current labels of conventional and certified “Made with Organic” pet food products containing materials included in this petition. The petitioned materials are underlined in these examples:

**Current conventional wet cat food label, with taurine, L-lysine and DL-methionine:**

Water, Beef, Beef By-Product, Pork By-Products, Pork Liver, Wheat Flour, Corn Starch, Rice Flour, Powdered Cellulose, Chicken Liver Flavor, Soybean Oil, Corn Gluten Meal, Calcium Sulfate, Guar Gum, Locust Bean Gum, Carrageenan, Brewers Dried Yeast, Dicalcium Phosphate, Iron Oxide, Calcium Carbonate, Choline Chloride, DL-Methionine, Taurine, Iodized Salt, L-Lysine, Potassium Chloride, Vitamin E Supplement, Thiamine Mononitrate, Zinc Oxide, Ferrous Sulfate, Niacin, Manganese Oxide, Copper Sulfate, Pyridoxine Hydrochloride, Calcium Pantothenate, Vitamin B12 Supplement, Riboflavin, Biotin, Calcium Iodate, Vitamin D3 Supplement, Folic Acid, Sodium Selenite.

**Current conventional dry cat food with taurine and L-arginine:**

Chicken By-Product Meal, Corn Gluten Meal, Brewers Rice, Whole Grain Corn, Animal Fat (preserved mixed tocopherols and citric acid), Powdered Cellulose, Chicken Liver Flavor, Lactic Acid, Soybean Oil, Soybean Mill Run, Potassium Chloride, Choline Chloride, Calcium Sulfate, Calcium Carbonate, Iodized Salt, Natural Flavor, DL-Methionine, Vitamin E Supplement, vitamins (L-Ascorbyl-2-Polyphosphate (source of vitamin C), Vitamin E Supplement, Niacin, Thiamine Mononitrate, Vitamin A Supplement, Calcium Pantothenate, Riboflavin, Biotin, Vitamin B12 Supplement, Pyridoxine Hydrochloride, Folic Acid, Vitamin D3 Supplement), Potassium Citrate, Taurine, Fish Oil, minerals (Ferrous Sulfate, Zinc Oxide, Copper Sulfate, Manganese Oxide, Calcium Iodate, Sodium Selenite), preserved with mixed Tocopherols and Citric Acid, L-Arginine, Phosphoric Acid, Beta-Carotene, Rosemary Extract.

**Current conventional dry cat food with taurine and DL-methionine:**

Chicken Meal, Ground Whole Corn, Corn Gluten Meal, Chicken Fat (Preserved with Mixed Tocopherols), Ground Whole Brown Rice, Ground Whole White Rice, Tomato Pomace (Source of Lycopene), Herring Meal, Avocado, Natural Flavor, Egg Product, Chicory Root, Salt, Whey, Potassium Chloride, Vitamins (Choline Chloride, a-Tocopherol Acetate (Source of Vitamin E), Niacin, Vitamin A Acetate, Thiamine Mononitrate (Source of Vitamin B1), Calcium Pantothenate, Pyridoxine Hydrochloride (Source of Vitamin B6), Menadione Sodium Bisulfate Complex, Riboflavin Supplement, Ascorbic Acid (Source of Vitamin C), Vitamin D3 Supplement, Vitamin B12 Supplement, Folic Acid, Biotin), Minerals (Zinc Sulfate, Zinc Amino Acid Chelate, Iron Amino Acid Chelate, Ferrous Sulfate, Copper Sulfate, Manganese Amino Acid Chelate, Copper Amino Acid Chelate, Manganese Oxide, Sodium Selenite, Calcium Iodate), Avocado Oil, Lecithin, Taurine, Calcium Carbonate, Parsley Flakes, Kelp Meal, DL-Methionine, Yucca Schidigera Extract, Inositol.

**Current dry dog food with taurine and L-carnitine:**

Required Amino Acid Organic Petition Information
Prepared by Crystal Springs Consulting, Inc.
Venison Meal, Dried Potatoes, Potato Starch, Potato Protein, Pea Protein, Sunflower Oil (preserved with mixed Tocopherols), Chicken Fat (preserved with mixed Tocopherols), Dried Plain Beet Pulp, Natural Flavors, Flaxseed, Potassium Chloride, Salt, Powdered Cellulose, Choline Chloride, Zinc Sulfate, Taurine, Vitamin E Supplement, Ferrous Sulfate, L-Ascorbyl-2-Polyphosphate (source of Vitamin C), Potassium Iodide, Copper Sulfate, L-Carnitine, Niacin Supplement, Calcium Pantothenate, Biotin, Manganese Oxide, Thiamine Mononitrate (Vitamin B1), Selenium, Vitamin A Supplement, Pyridoxine Hydrochloride (Vitamin B6), Riboflavin Supplement (Vitamin B2), Vitamin D3 Supplement, Vitamin B12 Supplement, Folic Acid, Rosemary Extract.

**Current certified “Made with Organic” dry cat food with taurine:**


**Current Certified “Made With Organic” dog food with L-carnitine:**


**Current Certified “Made With” dog food with taurine:**

Attachment B - Material Safety Data Sheets

Arginine

Material Safety Data Sheet
L-Arginine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Arginine
Catalog Number: SLA202, SLA203, SLA477
CAS #: 74-79-3
WEBC: C19306200
TSCA: TSCA Substances List: L-Arginine

Contact Information:
Scientifics.com, Inc.
(800) 205-0600
Fax: (800) 205-0601

Order Online: Scientifics.com

Section 2: Composition and Information on Ingredients

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Arginine</td>
<td></td>
<td>100</td>
</tr>
</tbody>
</table>

Section 3: Hazards Identification

Potential Acute Health Effects: Slightly hazardous in case of skin contact (irritant), of eye contact (irritant), of ingestion, of inhalation.

Potential Chronic Health Effects:

Section 4: First Aid Measures

Eye Contact:
Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Cold water may be used. Get medical attention if irritation occurs.
### Section 3: Fire and Explosion Data

**Flashpoint:** Not available.
**Autoignition Temperature:** Not available.
**Flammable Limits:** Not available.
**Flammability:** Not available.
**Fire Hazard Class:** Not available.
**Prod. of Comb. Ignit.:** Not available.
**Fire Hazard Class:** Not available.
**Explosion Hazard Class:** Not available.
**Prod. of Comb. Ignit.:** Not available.
**Explosion Hazard Class:** Not available.

**Notes:**
- Avoid contact with heat, strong oxidizing agents, strong reducing agents, strong alkalis, and strong acids.
- Use only with proper ventilation.
- Do not store in a damp or poorly ventilated area.
- Do not store near other hazardous materials.
- Do not store near sources of ignition.

### Section 4: Accidental Release Measures

**Small Spill:**
Use appropriate absorbent to remove spill from the area.

**Large Spill:**
Contact local emergency response personnel immediately.

**Precautions:**
Keep out of reach of children. Wash hands before eating, handling, or eating food. Wear appropriate protective clothing. Avoid contact with skin, eyes, and clothing.

### Section 7: Handling and Storage

- Store in a dry, well-ventilated area.
- Protect from moisture and direct sunlight.
- Keep away from heat, strong oxidizing or reducing agents.

### Section 8: Exposure Controls/Personal Protection

**Engineering Controls:**
- Use local exhaust ventilation or other means to control or remove the product to levels below the recommended exposure limit.
- Keep product at the recommended exposure limit.

**Personal Protection:**
- Wear appropriate protective clothing.
- Use a dust respirator.
- Use appropriate protective clothing.

**Personal Information in Case of a Large Spill:**
- Call 911 or local emergency response.

### Section 9: Physical and Chemical Properties

- **Physical state and appearance:** Solid (crystalline powder).
- **Odor:** Not available.
- **Melting Point:** Not available.
- **Boiling Point:** Not available.
- **Critical Temperature:** Not available.
- **Critical Pressure:** Not available.
- **Solubility:** Not available.

### Section 10: Stability and Reactivity Data

- **Stability:** Stable under normal conditions.
- **Decomposition:** May decompose at high temperatures.
- **Incompatibility:** Avoid contact with strong oxidizing agents.

---

**Prepared by Crystal Springs Consulting, Inc.**
Methionine

Material Safety Data Sheet
DL-methionine MSDS

Section 1: Chemical Product and Company Identification

Product Name: DL-methionine

Contact Information:

Section 2: Composition and Information on Ingredients

Composition:

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL-methionine</td>
<td>54-41-8</td>
<td>100</td>
</tr>
</tbody>
</table>

Section 3: Hazard Identification

Potential Acute Health Effects:

- In case of skin contact, wash affected area with mild soap and water. If necessary, seek medical attention.
- In case of eye contact, flush eyes with running water for at least 15 minutes. Keep eyes open. Seek medical attention.
- In case of exposure of mucous membranes (nose, mouth, throat), seek medical attention.
- In case of ingestion, seek medical attention immediately.

Section 4: First Aid Measures

Eye Contact:

- If contact occurs, immediately flush eyes with running water for at least 15 minutes. Keep eyes open. Seek medical attention.
- Do not use any eye cleansers. Seek medical attention immediately.

Section 5: Fire and Explosion Data

Flammability of the Product:

- May be combustible at high temperatures.

Autoignition Temperature:

- Not available.

Flash Point: Not available.

Flammable Limits: Not available.

Precautions:

- Combustible products can contain solvents (CO, CO2, nitrogen oxides, NOx, NOy...).

Fire Hazards in Presence of Various Substances:

- Not available.

Explosion Hazards in Presence of Various Substances:

- Not available.

Fire Behavior:

- Not available.

Flammable Limits:

- Not available.

Special Hazards:

- Not available.

Special Hazards:

- Not available.

Section 6: Accidental Release Measures

Small Spill:

- Use appropriateleaning to contain the spill and to avert contaminants to a disposal container. Finish cleaning by spreading water on the contaminated surface and dispose of according to local and regional authority requirements.

Large Spill:

- Use a method to contain the material into a convoluted waste disposal container. Finish cleaning by spreading water on the contaminated surface and allow to evaporate through the sanitary system.

Section 7: Handling and Storage

Precautions:

- Keep food, water, and clothing away from areas of contact. Avoid contact with skin and eyes.
- Do not breathe in dust or mist. Avoid direct contact with the skin and eyes. Do not inhale dust or fumes. Use personal protective equipment if necessary. Wash hands thoroughly after handling.

Prepared by Crystal Springs Consulting, Inc.
Storage:
Keep container dry. Store in a cool place. Ground all equipment containing materials. Keep container tightly closed. Keep in a cool, well-ventilated area. Combustible materials should be stored away from extreme heat and away from strong oxidizing agents.

Section 8: Exposure Controls/Personal Protection
Engineering Controls:
Use process or equipment controls, such as ventilation, to keep airborne levels below the recommended exposure limit. Appropriate personal protective equipment may include but are not limited to respirators and protective clothing.
Personal Protective Equipment:
Respirators: Use a NIOSH-approved respirator. Ventilation: Ensure proper ventilation to keep exposure levels below the exposure limit.

Section 9: Physical and Chemical Properties
Physical State and Appearance: Solid
Color: White
Solubility: Soluble in water

Section 10: Stability and Reactivity Data
Stability: The product is stable:

Section 11: Toxicological Information
Toxicity by Inhalation: LD50 Not available
Chronic Effects on Humans: Not available
Other Toxic Effects on Humans: None known in cases of skin contact, inhalation, or ingestion.

Section 12: Ecological Information
Biodegradability: Not available
Persistence: Not available

Section 13: Disposal Considerations
Waste Disposal:

Section 14: Transport Information
DOT Classification: Not applicable
SIC: Not applicable
NAICS: Not applicable

Section 15: Other Regulatory Information
Federal and State Regulations: Not applicable
Cysteine

Material Safety Data Sheet
L-Cysteine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Cysteine
Catalog Number: S630707
CAS Number: 52-75-7

Section 2: Composition and Information on Ingredients

Composition:

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Cysteine</td>
<td>52-75-7</td>
<td>100%</td>
</tr>
</tbody>
</table>

Section 3: Hazards Identification

Section 4: First Aid Measures

Skin Contact:
Check for and treat any contact areas. Immediately flush eyes with running water for at least 15 minutes, keeping eyelid open. Cold water may be used. Do not use an eye ointment. Seek medical attention.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combustible at high temperature.
Auto-Ignition Temperature: Not available.
Flash Point: Not available.
Flammable Limits: Not available.

Section 6: Accidental Release Measures

Small Spill:
Use appropriate tools to put the spilled solid in a convenient waste disposal container. Avoid contact with skin, eyes, clothing, or cartridges. Do not induce vomiting. If inhaled, move受害人 to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Seek medical attention.

Large Spill:
Use a fume hood to put the spilled material in a convenient waste disposal container. Avoid contact with skin, eyes, clothing, or cartridges. Do not induce vomiting. If inhaled, move受害人 to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Seek medical attention.

Section 7: Handling and Storage

Precautions:

Required Amino Acid Organic Petition Information
Prepared by Crystal Springs Consulting, Inc.

Page 57 of 117
Lysine
Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use process exhausts, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. Where operations generate dust, fumes or mist, use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:
Safety glasses. Lab coat. Dust respirator. Be sure to use an approved/identified respirator or equivalent. Gloves.

Section 9: Physical and Chemical Properties

- Physical state and appearance: Solid (Granular solid or Powdered solid)
- Odor: Not available
- Taste: Not available
- Molecular weight: 182.64 g/mole
- Color: White. Off-white
- pH (water/aqueous): Not available
- Flash Point: Not available
- Melting Point: Not available
- Critical temperature: Not available
- Specific Gravity: Not available
- Vapor pressure: Not available
- Vapor Density: Not available
- Volatility: Not available
- Odor Threshold: Not available
- Water/Oil Dist. Coeff.: Not available
- Solubility (in water): Not available
- Decomposition Properties: See solubility in water
- Sensitivity: Sensible in cylinder

Section 10: Stability and Reactivity Data

- Stability: The product is stable
- Reactivity: See above
- Conditions of instability: Excess heat, incompatible materials, dust generation.
Federal and State Regulations:

TSCA Inventory: Not included.

Other Regulations:

IEPC: This product is on the IEPC list of restricted chemicals.

Other Information:

Reactivity:

Health:

Physical:

Environmental:

Handling and Storage:

PPE:

Product Information:

General:

Risk:

Disposal:

Waste:

Other Information:

References:

Other Special Considerations:

+ 7200x2000 06.23.20

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Taurine

Material Safety Data Sheet
Taurine MSDS

Section 1: Chemical Product and Company Identification
Product Name: Taurine
Catalog Code: Q72014
CAS #: 79-20-0
MTBE: 105-59-9
TRCA: TPCA Add. Priority: Taurine
CMR: Not available
Synonyms: 2-Aminoethanesulfonic acid, 2-Aminooctanesulfonic acid, 2-Amino propanesulfonic acid, 2-Aminoethanesulfonic acid, 2-Aminoethanesulfonic acid
Chemical Name: Taurine
Chemical Formula: C2H7NO3S

Section 2: Composition and Information on Ingredients
Composition:
<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taurine</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Toxicological Data on Ingredients: Not applicable.

Section 3: Hazards Identification
Potential Acute Health Effects: slight nervousness or skin contact (rash), eye contact (irritation), ingestion, or inhalation.
Potential Chronic Health Effects: N/A.

Section 4: First Aid Measures
Eye Contact: Check for and remove any contact lenses. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Consult medical attention if irritation occurs.

Section 5: Fire and Explosion Data
Flash Point: Not available.
Lower Explosive Limit: Not available.
Flammable Limits: Not available.

Section 6: Accidental Release Measures
Small Spills: Use appropriate tools to put the spilled solid in a convenient sealable container. Finish cleaning by spreading water or the contaminated surface and dispose of according to local and national authority requirements.

Large Spills: Use a shovel to put the material into a convenient sealable container. Finish cleaning by spreading water on the contaminated surface and allow to evaporate through the sanitary system.

Section 7: Handling and Storage
Precautions: Keep away from sources of ignition. Store in a cool, dry, and well-ventilated area.

Required Amino Acid Organic Petition Information
Prepared by Crystal Springs Consulting, Inc.
Section 6: Exposure Controls/Personal Protection

Engineering Controls:
Use work practices, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If air is contaminated, ventilation is required to maintain concentrations below the exposure limit.

Personal Protection: Safety glasses. Lab coat. Dust respirator. Decontaminate Clothing. A self-contained breathing apparatus should be used to avoid inhalation of the product. Protective clothing including overalls may be necessary.

Exposure Limits: Not available.

Section 5: Physical and Chemical Properties

Physical and appearance: solid, crystalline solid, crystalline powder.
Color: cream.
Form: solid.
Molecular weight: 122.14 g/mole.
Density: 1.45 g/ml.
Melting point: 100°C.
Boiling point: 180°C.

Specific gravity: Not available.
Iodine value: Not available.
Flash point: Not available.
Evaporation rate: Not available.
Vapor density: Not available.
Solubility: Not available.
Dispersibility: Not available.

Section 10: Stability and Reactivity Data

Stability: The product is stable.
Radioactive contamination: Not available.
Conditions to avoid: Inert gas, dry environment, incompatible materials.

Section 11: Toxicological Information

Routes of Entry: Inhalation, Ingestion, Skin.
Toxicity to Animals: Oral and dermal (LD50 > 50 mg/kg, Rat)
Chronic Effects on Humans: Not available.
Other Effects on Humans: Irritating to skin, eyes, respiratory system.
Special Remarks on Toxicity to Animals: Not available.
Special Remarks on Toxicity: May cause irritation and skin sensitization.

Section 12: Ecological Information

Toxicity: Not available.
DOS and DOS: Not available.

Products of Biodegradation: May cause irritation and skin sensitization. May cause irritation and respiratory irritation. May cause respiratory sensitization. May cause respiratory irritation. The data presented in this substance have not been fully evaluated, may also affect behavior and respiratory sensitization.

Section 13: Disposal Considerations

Waste disposal:
Waste must be disposed of in accordance with federal, state, and local environmental control regulations.

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).
Identification: Not applicable.
Special Provision for Transport: Not applicable.

Section 15: Other Regulatory Information


Federal and State Regulations:  TSCA: Section 6(a), Inventory, Toxicity; other regulations: exempt. This product is on the European inventory of testing Commercial Chemical substances.

Other Considerations: Not considered under IARC; Health Canada - Not considered a food additive by Health Canada.

DOT: ADR: This product is not classified according to the ADR regulations. DG SDC: Avoid contact with skin and eyes. SDS: In case of contact with eyes, rinse immediately with plenty of water or eye/face wash. SDS: In case of contact with skin, wash immediately with plenty of water. SDS: Water soluble protective clothing.

HWR (GHS): Health Hazard: 1
Personal Protection: E
National Fire Protection Association (NFPA): Health: 1
Reactivity: 0
Specific hazard:
Protective Equipment: Gloves. Lab coat. Dust mask. Ensure to use a qualified respirator or equivalent. Safety glasses.

Section 10: Other information

References: Not available.
Other Special Considerations: Not available.

CREATED: 10/20/04 1:03:00 AM
LAST UPDATED: 10/20/04 1:03:00 PM

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# Tryptophan

![Material Safety Data Sheet](image.png)

## L-Tryptophan MSDS

### Section 1: Chemical Product and Company Identification

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Name</td>
<td>L-Tryptophan</td>
</tr>
<tr>
<td>CAS Registry Number</td>
<td>72-22-3</td>
</tr>
<tr>
<td>Synonyms</td>
<td>Tryptophan, L-tryptophan, 3-aminopyrrolidine-2-carboxylic acid</td>
</tr>
</tbody>
</table>

### Section 2: Composition and Information on Ingredients

<table>
<thead>
<tr>
<th>Component</th>
<th>CAS Number</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Tryptophan</td>
<td>72-22-3</td>
<td>100</td>
</tr>
</tbody>
</table>

### Section 3: Hazards Identification

- **Potential Acute Health Effects:** Slightly toxic in case of skin contact (amaretto), breathing, or ingestion, or inhalation.
- **Potential Chronic Health Effects:** Data not available.
- **Toxicological Effects:** Data not available.
- **Precautions for Safe Handling & Storage:** Data not available.

### Section 4: First Aid Measures

- **Skin Contact:** Wash skin with soap and water. If necessary, seek medical attention.
- **Inhalation:** Remove to fresh air. If breathing is difficult, give oxygen. Seek medical attention.
- **Eye Contact:** Rinse eyes with large quantities of cool water for 15 minutes. Seek medical attention.

### Section 5: Fire and Explosion Hazards

- **Fire Fighting:** Use water. Do not use foam. steam. Use dry chemical or carbon dioxide to extinguish fire. Avoid breathing dust or fumes.

### Section 6: Accidental Release Measures

- **General Measures:** Wash away spilled material using inert material. Do not put material into the sewer system. Dispose of the contaminated material in a suitable waste disposal system.

### Section 7: Handling and Storage

- **Precautions:** Wash hands thoroughly after handling. Use personal protective equipment. Store in a cool, dry place.
Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability Temperature: Not available.

Conditions of Instability: Erodes keratin, incompatible materials.

Incompatibility with other substances: React with reducing agents, acids.

Decomposition: Non-combustible in presence of glass.

Special Hazards on Reactivity: Product transient.

Special Hazards on Contact: Not available.

Polymerization: Will not occur.

Section 11: Toxicological Information

Route of Entry: Inhalation, ingestion.

Vapor: Inhaling, acute eye irritation: LD50 = 1500 mg/kg (rat).

Chronic Effects on Humans: HUMAN HEALTH EFFECTS: Mutagenic for bacteria and yeast.

Other Toxic Effects on Humans: Slight irritation in case of skin contact (injury) or ingestion, of inhalation.

Special Hazards on Reactivity: Not available.

Special Hazards on Contact: May cause chemical burns.

Special Hazards on Other Toxic Effects on Humans: May cause respiratory tract irritation. Ingestion: Causes severe irritative. May affect liver and kidney; vomiting; systemic depression; hypothermia, convulsions, nausea, headache, loss of appetite, urination, diarrhea. May cause respiratory tract irritation. Inhalation: May cause respiratory tract irritation.

Section 12: Ecological Information

Exposure: Not available.

Toxicity and CAD: Not available.

Products of Biodegradation: A product of biodegradation may not be toxic. However, a long-term degradation products may arise.

Toxicity of the Products of Biodegradation: The product itself and its products of degradation are not toxic.

Special Warnings on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations

Wastes Disposal: Waste must be disposed of in accordance with federal, state and local environmental control regulations.
Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States). Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations: TOCA (By Inventory Lethal): No problem. Other Regulations: CERCLA: This product is not on the Commercial Chemical Substances. Other Classifications: Wastes (Canada): Not controlled under MAPP (Canada). Risk Matrix: This product is not classified according to the EU regulations. EU/REACH: Avoid contact with skin and eyes. Health: (U.S.A.)

- Health hazard: 1
- Reactivity: 0
- Personal Protection: 0

Oxidation: 0

Specific hazard: None.

Protective Equipment: Gloves, lab coat, closed separator, the same to use an approved respirator or equivalent; safety glasses.

Section 16: Other Information

References: Not available.

Other Special Considerations: Not available.

Created: 10/1/2003 10:30 PM
Last Updated: 11/9/2018 12:00 PM

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Threonine

Material Safety Data Sheet
L-Threonine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Threonine

Contact Information:
isoarcadia.com, Inc.
WALCO Printer HD
MAILING ADDRESS

Section 2: Composition and Information on Ingredients

Composition:

<table>
<thead>
<tr>
<th>Name</th>
<th>CAS #</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Threonine</td>
<td>72-16-4</td>
<td>100</td>
</tr>
</tbody>
</table>

Section 3: Hazard Identification

Potential Acute Health Effects:
Hazardous in case of inhaled or otherwise ingested. Slightly hazardous in case of skin contact (orman). Hazardous in case of contact with eyes. In case of skin contact, avoid contact with eyes and skin. In case of skin contact, wash contaminated clothing before changing.

Systemic Toxicity: Not available.

Section 4: First Aid Measures

Eye Contact:
Rinse with plenty of water for at least 15 minutes, keeping eyelids open. Do not use water under pressure. Seek medical attention.

Section 5: Fire and Explosion Data

Flammability of the Product: May be combusitive at high temperature.

Auto-Ignition Temperature: Not available.

Flash Points: Not available.

Flammable Limits: Not available.

Materials to be avoided: These products are compatible with (CO, O2, nitrogen oxide (NOx)).

Fire Extinguishing Media:二氧化碳, 干粉, 化学泡沫. Not available.

Suppression Systems: In the presence of flammable materials, the Co2 extinguishing system is recommended. Not available.

Special Fire Fighting Procedures: Not available.

Section 6: Accidental Release Measures

Small Spill:
Use a clean, dry, absorbent, non-flammable material to contain the spill. Use a clean, dry, absorbent, non-flammable material to contain the spill. Do not allow spills to enter underground waterways.

Section 7: Handling and Storage

Precautions:
Keep away from heat, keep away from sources of ignition, thoroughly wet the equipment with water if necessary. Do not expose to water or steam. Avoid contact with eyes, mouth, and skin. Store in a cool, dry, well-ventilated area.

Health:
1
Fire:
1
Reactivity:
3
Precaution:
9

Required Amino Acid Organic Petition Information
Prepared by Crystal Springs Consulting, Inc.

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Section 6: Exposure Controls/Personal Protection

Engineering Controls:
Use process exhaust, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If use operations generate dust, fume or mist, use ventilation to keep exposure to airborne contaminants below the respective limit.

Personal Protective Equipment:
When gases, mists, or fumes are present, use gas masks. Use water if in a large spill. Select personal protective equipment based on the physical and chemical properties of the product.

Section 7: Physical and Chemical Properties

Physical State and Appearance: Solid
Odor: Not available
Texture: Not available
Monomer Weight: 116.12 g/mole
Color: Not available
pH of Solution: Not available
Solubility: Insoluble in most organic solvents
Melting Point: Decomposes at 122.9°C
Critical Temperature: Not available
Water Solubility: Not available
Water/Oil Relative Retention: Not available
Solubility in Water: Not available
Solubility in Non-aqueous Solvent: See stability in water
Stability: Stable in cold water

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Incompatibility: Temperature: Not available
Conditions of Instability: Not available
Decomposition with other substances: Not available
Decomposition in the presence of light:
Special Remarks on Reactivity: Not available
Special Remarks on Incompatibility: Not available

Section 11: Toxicological Information

Toxicity by Inhalation: Not available
Toxicity by Ingestion: Not available
Toxicity by Skin Contact: Not available
Chronic Effects on Humans: Not available

Other Toxic Effects on Humans:
Reproduction in mice in adults: Not available
Mutagenic in the presence of light: Not available
Mutagenic in the presence of light: Not available
Special Remarks on Chronic Effects on Humans: Not available
Special Remarks on other Toxic Effects on Humans: Not available

Section 12: Ecological Data

Biodegradability: Not available
Bioaccumulation: Not available
Toxicity to Aquatic Life: Not available
Toxicity to Soil Life: Not available

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT Hazardous Material (Hazard Class)
Identification: Not applicable
Special Precautions for Transport: Not applicable

Section 15: Other Regulatory Information
Federal and State Regulations: TSCA (Dr.) Inventory L-Threonine
Other Regulations: Not available.
Other Classifications:
Hazard (California): Non-control under 32.500 (California)
DNTC (Guides): Not recommended for use.
IMDR (I.C.A.):
Health: 1
Flammability: 0
Specific hazard:
Protective Equipment:
Gloves: Do not use. Dust respirator. Be sure to use an approved certified respirator or equivalent safety glasses.

Section 10: Other Information

References: Not available.
Other Caution Conclusions: Not available.
Created: 10/2006 09:32 AM
Last Updated: 10/2006 12:00 AM

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p. 5
## L-Histidine MSDS

### Section 1: Chemical Product and Company Identification

**Product Name:** L-Histidine  
**CAS Number:** [pending]  
**Physical Form:** Liquid  
**Chemical Formula:** C<sub>6</sub>H<sub>14</sub>N<sub>2</sub>O<sub>2</sub>  
**Chemical Name:** Histidine  
**Synonyms:**  

<table>
<thead>
<tr>
<th>Chemical Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histidine</td>
<td></td>
</tr>
</tbody>
</table>

**Prepared by Crystal Springs Consulting, Inc.**

### Section 2: Composition and Information on Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS Number</th>
<th>% by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-Histidine</td>
<td>[pending]</td>
<td>100</td>
</tr>
</tbody>
</table>

### Section 3: Hazards Identification

**Potential Acute Health Effects:**  
Hazardous in case of ingestion, of inhalation, slight to moderate in case of skin contact (intact), eye contact (intact).

### Section 4: First Aid Measures

**Eye Contact:**  
Immediatly flush eyes with running water for at least 15 minutes, keeping eyelids open. Get medical attention.

**Inhalation:**

**Ingestion:**

Do not induce vomiting. Loosen tight clothing such as a collar, tie, belt or restraint. If the victim is not breathing, perform Heimlich maneuver (if trained). Get medical attention.

### Section 5: Fire and Explosion Data

**Flammability of the Product:** Not combustible at high temperature.

**Flash Point:** Not available.

**Explosion Hazard:** Not applicable.

### Section 6: Accidental Release Measures

**Small Spill:**  
Use appropriate tools to put the solids solid in a convenient waste disposal container. Finish cleaning by dispersing water on the contaminated surface and dispose of according to local and regional authority requirements.

**Large Spill:**  
Use a method to put the material into a convenient waste disposal container. Finish cleaning by dispersing water on the contaminated surface and allow to drain through the sanitary system.

### Section 7: Handling and Storage

**Precautions:**

- Keep away from heat. Extras away from sources of ignition. Do not contain or store under a fire protective canopy or storage container. Do not handle or store in a metal container. Wear suitable protective clothing to prevent skin contact and follow the container's label instructions.
Section 8: Exposure Control/Personal Protection

Engineering Controls: Use process enclosures, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. If such operations generate dust, fume, or mist, use ventilation to help ensure that airborne contaminants do not exceed the exposure limit.

Personal Protective Equipment: Safety glasses. Dust mask, dust respirator, or dust respirator of equivalent type.

Permissible Exposure Limit: Not available.

Section 9: Physical and Chemical Properties

Physical and appearance: Not available.

Color: Not available.

Trade name: Not available.

Melting point: Deodorized.

Boiling point: Deodorized.

Flash point: Not available.

Saponification value: Not available.

Vapor density: Not available.

pH: Not available.

Color: Not available.

Odor: Not available.

Stability: Not available.

Spontaneous combustion: Not available.

Dispellability: Soluble in water.

Section 10: Stability and Reactivity Data

Stability: Not available.

Reactivity: Not available.

Hazardous decomposition products: Not available.

Other Information: Not available.

References: Not available.

Other Special Considerations: Not available.

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Section 11: Toxological Information

Routes of Entry: Inhalation, ingestion.
Toxicity for Animals: Acute oral toxicity (LD50): 1000 mg/kg (Mice).
Chronic Effects: Unknown. The substance is toxic to large, chronic mammals.
Special Remarks on Toxicity to Animals: No irritation.
Special Remarks on Chronic Effects on Humans: Passes through the placental barrier in humans.
Special Remarks on Other Toxic Effects on Humans: None reported.

Section 12: Ecological Information

Toxicity: Not available.
Bioaccumulation: Not available.
BOD5 and COD: Not available.
Other effects: Metabolism:
Properly labeled short-term degradation products are not known, however, long-term degradation products may arise.
Toxicity of the Products of Biodegradation: The products of degradation are toxic.
Special Remarks on the Products of Biodegradation: Not available.

Section 13: Disposal Considerations


Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).
Identification: Non-hazardous
Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

Federal and State Regulations: TSCA and Inherently Limited.
Other Regulations: SARA, National Package
Other: Not applicable.

Section 16: Other Information

References: Not available.
Other Special Considerations: Not available.

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Isoleucine

Material Safety Data Sheet
L-Isoleucine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Isoleucine

Contact Information:

International: 1-800-825-6500

Section 2: Composition and Information on Ingredients

Composition:

Chemical Name:

L-Isoleucine

CAS Number:

72-32-5

Toxicological Data on Ingredients: L-Isoleucine LD50 not available, LC50 not available.

Section 3: Hazards Identification

Potential Acute Health Effects:

Inhalation:

Very hazardous in case of contact; irritation of respiratory tract, nose, throat, and eyes. Inhaling the dust may lead to irritation of the respiratory tract and eyes.

Ingestion:

Very hazardous in case of contact; irritation of respiratory tract, nose, throat, and eyes. Inhaling the dust may lead to irritation of the respiratory tract and eyes.

Skin Contact:

Very hazardous in case of contact; irritation of skin, eyes, and respiratory tract. Inhaling the dust may lead to irritation of the respiratory tract and eyes.

Eye Contact:

Very hazardous in case of contact; irritation of skin, eyes, and respiratory tract. Inhaling the dust may lead to irritation of the respiratory tract and eyes.

Inhalation:

Very hazardous in case of contact; irritation of skin, eyes, and respiratory tract. Inhaling the dust may lead to irritation of the respiratory tract and eyes.

Section 4: First Aid Measures

Eye Contact:

Flush eyes with large amounts of water for at least 15 minutes. Seek medical attention.

Skin Contact:

Wash with large amounts of water. If systemic effects occur, seek medical attention.

Inhalation:

Seek medical attention immediately.

Ingestion:

Seek medical attention immediately.

Section 5: Fire and Explosion Data

Flammability of the Product:

May be flammable at high temperatures.

Auto-Ignition Temperature:

Not available.

Flash Point:

Not available.

Vapor Pressure:

Not available.

Explosion Hazards:

Not available.

Fire Extinguishing Media:

Water spray, dry chemical, carbon dioxide, or metal fire extinguisher. Do not use water jet or foam.

Special Fire Fighting Procedures:

Use water spray to suppress fire. Use water to cool the container if a fire develops.

Section 6: Accidental Release Measures

Small Spill:

Use appropriate equipment to contain spill. Use paper towel to cover spill and allow to evaporate.

Large Spill:

Use appropriate equipment to contain spill. Use paper towel to cover spill and allow to evaporate.

Section 7: Handling and Storage

Precautions:

Wear appropriate eye, skin, respiratory, and protective clothing when handling. Avoid contact with skin, eyes, and respiratory tract. Use appropriate equipment to contain spill. Use paper towel to cover spill and allow to evaporate.
Section 6: Exposure Controls/Personal Protection

Engineering Controls:
Use process exhaust, local exhaust ventilation, or other engineering controls to keep airborne levels below recommended exposure limits. Fan operations generate dust, fumes, or mist; use ventilation to keep exposure to airborne contaminants below the exposure limit.

Personal Protection:
Spectacles. Use safety goggles or rigid face shield. Face shield is required when there is potential for splash or spray. A self-contained breathing apparatus should be used to avoid inhalation of the product. Suggested protective clothing might include: rubber or neoprene or rubber, neoprene, or polyethylene gloves, rubber boots, rubber apron, rubber or neoprene or rubber, neoprene, or polyethylene overshoes, goggles, and respirator. Use NIOSH-approved respirator. Use NIOSH-approved respirator. Use NIOSH-approved respirator.

Section 3: Physical and Chemical Properties

Physical State and Appearance: Solid (unclouded) liquid.
Odor: Not available.
Texture: Not available.
Melting Point: Depression: -25°C or -45 ºC.
Critical Temperature: For available.
Specific Gravity: Not available.
Vapor Pressure: Not available.
Vapor Density: Not available.
Vapor Pressure: Not available.
solubility in Water: Not available.
Dispersions Properties: Gas solubility in water.
Solubility: Partially soluble in cold water.

Section 10: Stability and Reactivity Data

Stability: The product is stable.

Instability: Temperature: Not available.
Conditions of Instability: Not available.
Incompatibility: with various substances: Not available.
Compatibility: Not available. In contact with glass, rubber, neoprene, or polyethylene.
Special Remarks on Reactivity: Not available.
Polymerization: No.

Section 11: Toxicological Information

Routes of Entry: Oral contact, eye contact, inhalation, ingestion.
Toxicity for animals: LD50: Rat, intraperitoneal: 500 mg/kg, 2000 mg/kg, not available.
Chronic Effects on humans: Not available.
Other Toxic Effects on humans: Not available.
Specific effects on animals: Not available.
Specific Remarks on Chronic Effects on animals: Not available.
Specific Remarks on other Toxic Effects on animals: Not available.

Section 12: Ecological Information

Toxicity: Not available.
MOOC and CDPH: Not available.
Effects of Degradation: Short-term degradation products are not likely, however, long-term degradation products may occur.
Toxicity of the Products of Degradation: The products of degradation are not toxic.
Specific Remarks on the Products of Degradation: Not available.

Section 13: Disposal Considerations

Waste Disposal:

Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).
Identification: Not applicable.
Specific Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

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Leucine

Material Safety Data Sheet
L-Leucine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Leucine
Contact Information:

Section 2: Composition and Information on Ingredients

Composition:

Section 3: Hazard Identification

Potential Acute Health Effects:

Skin Reactions: Not available.
Respiratory Tract: Not available.
Gastrointestinal: Not available.
Ingestion: Not available.
Inhalation: Not available.
Eye Contact: Not available.
Eye Contact: Not available.

Section 4: Personal Protective Equipment

Section 5: Fire and Explosion Data

Hazard Class: Not available.
Hazard Category: Not available.

Section 6: Stabilization and Reactivity

Section 7: Handling and Storage

Precautions:

Storage:

Required Amino Acid Organic Petition Information
Prepared by Crystal Springs Consulting, Inc.
Section 8: Exposure Controls/Personal Protection

Engineering Controls:
Use properly functioning local exhaust ventilation, or other engineering controls to keep airborne and/or dust to recommended exposure limits. If local exhaust systems are not sufficient, use respiratory protection.

Personal Protective Equipment:
Dry, dust-proof, lab coat.

Section 9: Physical and Chemical Properties

Physical State and Appearance: Solid
Color: Not available
Texture: Not available
Molecular Weight: 121.17 g/mole
Density: Not available
pH (1% aqueous): Not available
Melting Point: Not available
Boiling Point: Not available
Critical Temperature: Not available
Vapor Density: Not available
Solubility (g/100mL dist. water): Not available
Solubility in other solvents: Not available

Dispersion Properties: Gas solubility in water

Stability: Stable in cold water

Section 10: Stability and Reactivity Data

Stability: No data available
Incompatibility: Not available
Conditions of Stability: Not available
Incompatibility with reactive substances: Not available

Special Remarks: None

Section 11: Toxicological Information

Routes of Entry: Skin, eyes, ingestion, inhalation, ingestion
Toxicity to Animals:
LD50: Not available
LC50: Not available

Chronic Effects on Humans: Not available

Acute Toxicity to Animals:
LD50: Not available
LC50: Not available

Special Remarks: None

Section 12: Ecological Information

Biodegradability: Not available

Section 13: Transport Information

DOT Classification: None

Section 15: Other Regulatory Information

Federal and State Regulations:
TSCA No.

Other Regulations:
CERCLA: Not subject to the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC 9602).

International:
GLAAS: Not a hazardous material under the regulations of the International Regulations for the Transport of Dangerous Goods (Bogota, 1992).

Contact Information:
Prepared by Crystal Springs Consulting, Inc.
Prepared by Crystal Springs Consulting, Inc.
## Section 18: Other Information

**Reference:** Not available

**Other Special Considerations:** Not available.

**Graded:** 00 (2021-05-21 PM)

**Last Updated:** 11/02/2010 12:39 PM

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Phenylalanine

Material Safety Data Sheet
L-Phenylalanine MSDS

Section 1: Chemical Product and Company Identification

- Catalog Code: SUP071, SUP092, SUP181
- CAS #: 63-13-2
- RTECS: AY750200
- FEDRA: TCA-160-003; FEDRA: L-Phenylalanine
- DIN: 1,775,255
- Synonyms: L-Phenylalanyl, L-Phe, L-Phenylalanine, L-Phe, Phenylalanine
- Chemical Formula: C9H11NO2

Contact Information:
- snowmanlabs.com, Inc.
- 14825 S Richfield Road
- 1-800-881-7541; 818-776-9610
- international: +1-805-481-4630
- OSHA: epmsdata.com
- Chemical: purifi.com
- Emergency Telephone: call 1-800-456-0070
- For non-emergency assistance: call 1-310-496-4000

Section 2: Composition and Information on Ingredients

- Composition:
  - Name
  - CAS Number
  - % by Weight
  - C9H11NO2

- Toxicological Data on Ingredients: L-Phenylalanine (LD50): not available. LC50: not available.

Section 3: Hazards Identification

Potential Acute Health Effects:
- In case of skin contact (immediate): wash skin thoroughly with soap and water. In case of contact (immediate): wash skin thoroughly with soap and water.

Potential Chronic Health Effects:
- In case of eye contact (immediate): wash eyes with plenty of water. In case of exposure: wash skin thoroughly with soap and water.

Section 4: First Aid Measures

Eye Contact:
- Wash the affected eye(s) thoroughly with running water for at least 15 minutes, keeping eyelids open. Cold water may be used. Do not use an eye ointment, take medical attention.

Section 5: Fire and Explosion Data

- Inflammability of the Product: flammable.
- Oxidizing Properties: not applicable.
- Reactivity: not applicable.
- Maximum Allowable Pressure (Internal): not applicable.
- Maximum Allowable Pressure (External): not applicable.

Section 6: Accidental Release Measures

- Large Spills:
  - Use personal protective equipment appropriate for the operation.

Section 7: Handling and Storage

- Storage:
  - Store under conditions of temperature and humidity as specified elsewhere on the label.

- Transportation and Storage:
  - Store in a cool, dry place away from direct sunlight.
Section 8: Exposure Controls/Personal Protective

Engineering Controls:

Local exhaust ventilation, good housekeeping, and other engineering controls to reduce airborne levels below OSHA recommended exposure limits. If local exhaust ventilation is not possible, use personal protective equipment to reduce occupational exposure below OSHA exposure limits.

Personal Protective Equipment:


Section 9: Physical and Chemical Properties

Physical State and Appearance: White, odorless, dry powder.

Odor: Odorless.

Taste: Not applicable.

Molecular Weight: 95.15 g/mole.

pKa (if applicable): Not applicable.

Density: Not applicable.

Melting Point: Not applicable.

Boiling Point: Not applicable.

Critical Temperature: Not applicable.

Critical Pressure: Not applicable.

Vapor Density: Not applicable.

Viscosity: 0 cP.

Color: White.

Flammable Limits: Not applicable.

Solubility: Not applicable.

Depression Point: 0 °C.

Refractive Index: 1.015.

Section 10: Stability and Reactivity Data

Stability: Stable under normal conditions.

Conditions to Avoid: Not applicable.

Incompatibilities: Not applicable.

Decomposition Products: Not applicable.

Fire Extinguishing Media: Not applicable.

Special Hazards in Fire Fighting: Not applicable.

Special Hazards in Handling: Not applicable.

Stability of Materials in Storage: Not applicable.

Section 11: Toxicological Information

Routes of Entry: Inhaling, Ingestion, Injection, Inhalation.

Toxicity to Ingestion: LD₅₀ Not available. LC₅₀ Not available.

Other Toxic Effects: Not applicable.

Hazardous Combustion Products: Not applicable.

Special Remarks on Toxicity: None known.

Special Remarks on Combustion: Not applicable.

Polynuclear Aromatic Hydrocarbons: Not available.

Section 12: Ecological Information

Persistence: Not available.

Biodegradability: Not available.

Bioaccumulation: Not available.

Toxicity to Other Species: Not available.

Special Remarks on Ecological Effects: Not applicable.

Special Remarks on Other Toxic Effects: Not applicable.

Section 13: Disposal Considerations

Waste Treatment

Disposal Methods: Not applicable.

Section 14: Transport Information

DOT Classification: Not a DOT regulated material.

Identification: Not applicable.

Section 15: Other Regulatory Information

Required Amino Acid Organic Petition Information

Prepared by Crystal Springs Consulting, Inc.
Tyrosine

Material Safety Data Sheet
L-tyrosine MSDS

Section 1: Chemical Product and Company Identification

Product Name: L-Tyrosine

CAS No.: 90-03-5

Supplier Information:

Solvay Chemicals, Inc.
1000 South 2nd Street, Suite 100
Minneapolis, MN 55401

Emergency Telephone Numbers:

Emergency (U.S.): 1-888-874-4444
International: 1-800-888-7272

Section 2: Composition and Information on Ingredients

Table of Ingredients:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No.</th>
<th>% by Weight</th>
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</thead>
<tbody>
<tr>
<td>Tyrosine</td>
<td>90-03-5</td>
<td>100</td>
</tr>
</tbody>
</table>

Section 3: Hazards Identification

Potential Acute Health Effects:

Skin: In case of contact, wash immediately with plenty of water for at least 15 min. Use soap and water if necessary. May irritate skin. Use suitable protective gloves.

Eye: In case of contact, flush eyes with running water for at least 15 min. May cause irritation and redness. Avoid breathing the dust. Use safety glasses and a face mask.

Potential Chronic Health Effects:

Skin irritation and contact dermatitis may be caused by prolonged contact or repeated exposure. No information is available on effects on the respiratory tract or the eyes.

Section 4: First Aid Measures

Eye Contact:

Flush eyes with large amounts of cool water for at least 15 min. Use a broad spectrum contact lens for protection. Do not attempt to remove contact lenses.

Skin Contact:

Wash affected skin with soap and water for at least 15 min. Use soap and water if necessary. If irritation persists, seek medical attention.

Section 5: Fire and Explosion Data

Flammability of the Material:

Not flammable.

Auto-Ignition Temperature: Not available.

Flash Point: Not available.

Products of Combustion:

Tyrosine is not expected to produce toxic or hazardous combustion products.

Section 6: Accidental Release Measures

Small Spill:

Use an appropriate absorbent to contain the spill and prevent it from reaching storm drains or sewers. Use a water mist to control the spread of the spill. Use a water spray to control the spread of the spill.

Large Spill:

Use an appropriate absorbent to contain the spill and prevent it from reaching storm drains or sewers. Use a water spray to control the spread of the spill.

Section 7: Handling and Storage

Handling:

Handle under conditions that ensure no contact with skin. Use appropriate personal protective equipment when handling large quantities. Do not inhale dust or fumes.

Storage:

Store under conditions that ensure no contact with skin. Use appropriate personal protective equipment when handling large quantities. Do not inhale dust or fumes.
Section 14: Transport Information

DOT Classification: Not a DOT controlled material (United States).
Identification: Not applicable.
Special Provisions for Transport: Not applicable.

Section 15: Other Regulatory Information

FEDERAL REGULATIONS: OSHA, HCS
Other Regulations: EN7000: This product is on the European Inventory of Existing Commercial Chemical Substances.
Other Classifications:
Waste (Canada): Non-hazardous under DDB01 (Canada).
ENGLAND: This medium is not classified according to the EU regulations. SCENAR-Avoid contact with skin and eyes. SCENAR-After contact with skin, wash immediately with plenty of water. SCENAR-After contact with eyes, SCENAR-In case of accident or if you feel unwell, seek medical advice immediately (4-hour emergency center below). SCENAR-HMM (C.I.A.):
- Health Hazard: 1
- Fire Hazard: 1
- Reactivity: 0
- Personal Protection: 4
- National Fire Protection Association (NFPA):
  - Health: 1
  - Flammability: 1
  - Reactivity: 0
  - Special Hazards:
  - Protective Equipment:
  - Gloves, Lab coat, Dust mask. Be sure to use an approved certified respirator or equivalant safety glasses.

Section 16: Other Information

Distributor: Not available.
Other Special Considerations: Not available.
Creation: 09/08/20 12:00 PM
Last Updated: 11/09/20 12:12 PM

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Valine
Section 8: Physical and Chemical Properties

Physical state and appearance: Cold, white powder.

Color: Not assessable.

Odor: Not assessable.

Molecular weight: 117.1 g/mole.

Form: Soluble.

pH (aqueous): Not assessable.

Density: Not assessable.

Melting Point: Not assessable.

Critical Properties: Not assessable.

Vapor Pressure: Not assessable.

Vapor Density: Not assessable.

Solubility: Not assessable.

Stability: Not assessable.

Semicrystalline: Not assessable.

Volatility: Not assessable.

Section 9: Stability and Reactivity Data

Stability: Not assessable.

Reactivity: Not assessable.

Conditions of instability: Not assessable.

Stability: Not assessable.

Incompatibility with previous substances: Not assessable.

Chemical stability: Not assessable.

Physical stability: Not assessable.

Compatibility: Not assessable.

Special Remarks on Reactivity: Not assessable.

Special Remarks: Not assessable.

Prepared by Crystal Springs Consulting, Inc.
June 27, 2011

Ms. Shannon Nally
Standards Division
United States Department of Agriculture
National Organic Program
1400 Independence Avenue SW
Room 2646-S, STOP 0268
Washington, District of Columbia 20250

Dear Ms. Nally:

We are responding to your e-mail request of May 31, 2011 for clarification on how the United States Food and Drug Administration (FDA) determines which nutrients are required in the diets of animals other than man and the acceptability of ingredients used to supplement animal diets in order to meet specific nutrient requirements.

The regulations in Title 21 of the Code of Federal Regulations (21 CFR) Parts 500 to 599 [21 CFR 500-599] that pertain to the labeling and formulation of animal feeds, including foods for dogs and cats, do not contain a corresponding or homologous Part to 21 CFR 104, Nutritional Quality Guideline for Foods which applies ONLY to foods for people. Part 104 of 21 CFR sets Daily Reference Values (DRV) or Recommended Daily Intakes (RDI) for 21 nutrients that may be added to certain foods for people under the conditions specified within the regulation.

The Center for Veterinary Medicine (CVM) is the Center within FDA that has regulatory authority over animal feeds and the ingredients used to formulate animal feed products. For animal feeds, including foods for dogs and cats, the CVM has not established or promulgated any minimum requirements (MR), adequate intakes (AI), recommended allowances (RA) or other reference standards for daily nutrient intakes for any particular nutrient. The CVM relies on the various ad hoc expert nutrition committees under the Committee on Animal Nutrition of the National Research Council in the National Academy of Sciences for establishment of which nutrients, and in what amounts, are essential in the diets for specific species of domestic animals to meet that species’ daily nutrient requirements. For dogs and cats, the required essential nutrients are listed and described in the 2006 edition of Nutrient Requirements of Dogs and Cats.1 The CVM considers the nutrients listed in Tables 15-3, 15-5, 15-8, for dogs, and Tables 15-10, 15-12, 15-14 for cats, to be essential nutrients and eligible for supplementation if required to meet and provide the listed MR, or in the absence of a stated value for the MR then the listed value for AI for that nutrient, in products represented to be “complete and balanced.”

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FDA regulates the ingredients added to animal foods, one purpose of which can be to supply nutrients to the finished product. Ingredients that FDA finds acceptable for inclusion in animal feeds may be found in several lists, publications and locations. Title 21 CFR Part 573, Food Additives Permitted in Feed and Drinking Water of Animals lists the additives that FDA has formally approved for the indicated intended use contained in the specific regulations. Substances that are generally recognized as safe (GRAS) for an intended use in animal feeds are listed in 21 CFR 582 and 21 CFR 584. The CVM has recently initiated a GRAS Notification Pilot Program similar to the GRAS Notification Pilot Program for ingredients in foods for people administered by the FDA Center for Food Safety and Applied Nutrition. Although at the time of this letter no substances have completed the CVM GRAS Notification process, eventually substances for which CVM has no questions regarding a GRAS determination made by a stakeholder will be indicated at http://www.fda.gov/AnimalVeterinary/Products/AnimalFoodFeeds/GenerallyRecognizedasSafeGRASNotifications/ucm192224.htm. Finally, although not formally approved through the food additive approval process or reviewed under the GRAS Notification Pilot Program, CVM generally allows the use of ingredients defined in Official Names and Definitions of Feed Ingredients in the Official Publication (OP) of the Association of American Feed Control Officials (AAFCO) in animal feeds within the specifications or restrictions contained in a particular ingredient’s definition. At this time the Official Names and Definitions of Feed Ingredients in the OP of the AAFCO is likely the most comprehensive listing of ingredients acceptable for use in animal feeds.

Many dog and cat foods, possibly even the majority, are formulated to be complete nutrition products, similar in concept and objective to total mixed rations for cattle and complete feeds for swine and poultry. It is generally not possible to attain all required nutrients from a combination of typical food ingredients used to make dog and cat foods without including one or more specific nutrient supplements in the products. This is especially true for one or more required vitamins, minerals, and a few amino acids, and such nutrient supplements are not likely to meet the definition or standard for being organically produced. The National Organic Program (NOP) undoubtedly will have encountered such occurrences in the diets (or rations) required for cattle to produce organic milk and for the production of pork or poultry that can be labeled as organic. A notable required nutrient for cats that will likely not have merited consideration in the diets of other organic feeds is a requirement for the beta-sulfonic amino acid taurine. Because of losses in taurine content during processing and because taurine deficiency manifests as serious, irreversible blindness, heart failure, reproductive, and developmental failure, all complete cat foods are supplemented with synthetic taurine. The food additive regulation for taurine at 21 CFR 573.980 is for use in the feed of growing chickens. However, given the scientific determinations of the need for taurine in the diets of cats and the National Research Council’s declaration of taurine as being essential for cats, CVM has not objected to inclusion of taurine in the diets for cats. The feed ingredient definition 6.12 for taurine in the OP of the AAFCO indicates it may be used in the diets for cats and dogs. There may be other nutrient-supplement ingredients specific to dog and cat foods that the NOP Standards Board has not considered before in regards to the formulation of diets for other animal species. Taurine is simply the most obvious example.
Your e-mail mentions the AAFCO Dog and Cat Food Nutrient Profiles. These profiles contain a list of required nutrients and recommended concentrations for those nutrients in dog or cat food products if a manufacturer wants to claim the product is complete and balanced based on the product containing the nutrient concentrations listed in the particular profile. Such claims are enforced by various states through the state’s feed laws and regulations if that state has adopted the AAFCO Model Regulations for Pet Food and Specialty Pet Food that are also contained in the OP of the AAFCO. The AAFCO Dog and Cat Food Nutrient Profiles do not contain any nutrient that has not been determined to be essential and listed in the previously referenced tables in the 2006 edition of Nutrient Requirements of Dogs and Cats. The 2006 edition of Nutrient Requirements of Dogs and Cats contains some additional specific fatty acids as essential required nutrients for specific life stages of dogs and cats that are not currently listed in the AAFCO Dog and Cat Food Nutrient Profiles. The AAFCO Dog and Cat Food Nutrient Profiles are presently under consideration for revision, but what the specific revisions will be cannot be stated at this time. As previously indicated, FDA CVM relies on the Committee on Animal Nutrition of the National Research Council in the National Academy of Sciences for establishment of which nutrients are essential in the diets of animals, not the AAFCO Dog and Cat Food Nutrient Profiles.

In terms of concentrations of nutrients to meet some reference standard for daily nutrient intakes, the values in the AAFCO Dog and Cat Food Nutrient Profiles generally are equivalent to the AI or the RA amounts listed in the 2006 edition of Nutrient Requirements of Dogs and Cats. This is to provide a safety factor to ensure that minimum requirements are met should any interference in nutrient availability occur due to interactions between ingredients or from nutrient losses over the product’s shelf life. Such formulations above absolute minimum requirements will generally not dictate whether a specific nutrient supplement is needed to be used, as in the case of taurine discussed above. The need for supplementation will exist regardless, only the amount used to meet a given reference standard will vary.

I hope the information in this letter is helpful in clarifying the following points:

1. The nutrients FDA consider essential in dog and cat foods and the source of the designation for essentiality.

2. The various listings for ingredients the FDA considers to be acceptable for use in animal feeds, including ingredients for supplementation of specific nutrients in diets for animals. Please note, such ingredients may not meet the National Organic Program’s criteria for being considered acceptable in organic products, but are acceptable for use in animal feeds under FDA’s policies and authority.

You may contact me by telephone (240-453-6865), telefacsimile (240-453-6882) or email (william.burkholder@fda.hhs.gov) and refer to DAF 11177 if you have any questions concerning the content of this letter.

Sincerely,

William J. Burkholder, DVM, PhD, DACVN
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Attachment D - NRC Discussion on Protein and Amino Acids

Protein and Amino Acids

BASIC CONCEPTS

Introduction

Dogs have been used as a model for the study of human nutrition for nearly two centuries. Magendie (1816) was the first to demonstrate that protein was essential for life by showing that olive oil or sugar alone would not support life, but if protein was added, the dogs were in better condition for a much longer period of time. These early experiments and many others were confounded by the lack of knowledge and appreciation of the need for essential micronutrients. Nevertheless, it was clearly understood that protein was essential in the diet. The Magendie Commission was appointed in 1815 to evaluate the nutritive value of gelatin. In 1841, it reported (cited by McCollum, 1957) that dogs could not be maintained when fed gelatin alone. This led to the testing of other purified proteins with the result that no purified protein, when fed alone without other food ingredients, could maintain a dog in good health. Despite the lack of knowledge of the essentiality of micronutrients, over a period of a few decades there came a realization that the quality (amino acid composition) of protein in dog diets was important (Chittenden, 1904). In 1905, Kaufmann reported that dogs maintained nitrogen equilibrium when fed a gelatin-based diet supplemented with tyrosine, cystine, and tryptophan. Later work with rats showed that a similar diet was not nutritionally adequate (Jackson et al., 1928). The concentrations of other essential amino acids were too low to meet the requirement of animals for maintenance. Nevertheless, nutritional research with dogs helped establish that certain amino acids present in protein were essential in the diet. Although Abernethy and coworkers were able to formulate satisfactory diets for dogs using protein hydrolsates during the early part of the twentieth century, they were never successful in formulating a satisfactory diet using amino acids as the sole nitrogen source (Abernethy et al., 1912). This feat had to wait until Rose isolated and charac-

terized threonine, the last essential amino acid to be discovered that is required by all animals (McCoy et al., 1935). In 1939, Rose and Rice reported a slight positive nitrogen balance in dogs fed amino acid diets containing the same 10 essential amino acids that are required for the growing rat. They also reported that the removal of arginine had no effect on nitrogen equilibrium, whereas later work (Burns et al., 1981) showed that arginine was an essential amino acid for the adult dog. Since Rose and Rice did not publish the composition of the diet they used, the difference between the two studies remains unexplained.

Cats were not used as early or as routinely in nutrition experiments on the essentiality of protein and amino acids as were dogs. One early experiment using cats that had general application was published by Bidder and Schmidt in 1852 in which they showed, using controlled experimental conditions, that after cats ingested all the meat they could eat during a 7-day period, all of the dietary nitrogen (except 0.7 percent, which was within experimental error) was found in feces and urine and none was released as nitrogen gas. Nevertheless, it was not until the middle of the twentieth century that Da Silva and coworkers (1950a,b) and Allison and coworkers (1956) designed satisfactory purified diets that cats would eat readily, and cats could then be used effectively in nutrition research. Not until 1979 were the same 10 amino acids shown to be essential for cats as for dogs and other animal species (Rogers and Morris, 1979).

Structure and Function

With the exception of proline, all amino acids present in most proteins are α-amino acids and have α-amino and α-carboxyl groups, both of which are involved in the peptide bonds that are essential for protein structure. Each amino acid has a side chain on the α-carbon that ranges in size from a hydrogen atom to an indole ring. The various side chains contribute to the secondary and tertiary structure of protein, and several are often conjugated to various other

III
groups such as phosphate and amino sugars. Also of nutritional importance are the acidic and basic side chains in proteins that can accept or donate protons, depending on the pH of the medium in which the protein is present. Acid-precipitated proteins (e.g., casein) have protons added to the carbonyl group side chains. These protons, together with those on the basic side chains, are released during digestion, absorption; and utilization and contribute to metabolic acidosis. Amino acids are important in providing building blocks for many important biologically active compounds plus countless peptides and proteins. The sensory perception of purified proteins per se is that they are quite bland, whereas peptides and free amino acids have various tastes for humans that range from bitter (e.g., phenylalanine, tryptophan, sweet (e.g., glycine, threonine), umami (monosodium glutamate), or combinations thereof. The D-amino acids often have a different taste; for example, D-tryptophan is many times sweeter than sucrose. Whether dogs and cats perceive (taste) amino acids in the same way as humans is not known; however, selection of amino acids such as leucine by the cat and different neuroreponses by cats and dogs indicate some differences in taste perceptions of different amino acids.

Essentiality of Amino Acids

Dietary protein is required for two reasons. First, protein provides amino acids that dogs and cats cannot synthesize (essential amino acids) but are required for synthesis of the many proteins in the body. Second, protein provides dispensable amino acids (amino acids that can be synthesized if appropriate nitrogen and carbon sources are provided) that animals need for maintenance, growth, gestation, and lactation. Dispensable amino acids provide nitrogen and carbon for the synthesis of any needed dispensable amino acid for gluconeogenesis and/or energy. Dispensable amino acids also provide nitrogen and/or structural components necessary to make other compounds that are essential for life, such as purines, pyrimidines, heme, various hormones, neurotransmitters, and/or neuromodulators (e.g., thyroxine, catecholamines, γ-aminobutyric acid, taurine). For either dogs or cats that consume primarily animal tissue, amino acids also provide carbon chains for gluconeogenesis to supply glucose to tissues that require it (e.g., red blood cells, nervous tissue) to maintain normal tissue metabolism. As for most other animals, the following 10 amino acids have been shown to be essential for both dogs and cats: arginine (Arg), histidine (His), isoleucine (Ile), leucine (Leu), lysine (Lys), methionine (Met), phenylalanine (Phe), threonine (Thr), tryptophan (Trp), and valine (Val). In omnivores and certain herbivores (e.g., rats, chicks), removal of a single essential amino acid results in a decrease in food intake that is known to be a primary neuroresponse caused by the lack of the limiting essential amino acid (Gietzen, 1993). In cats, the limited work available (e.g., Hardy et al., 1977; Rogers and Morris, 1979) shows that food intake does not decrease as quickly as in rats after initial consumption of a diet devoid of an essential amino acid. Although food intake does decrease with time, the depression is not as severe as in omnivores and herbivores. The depression of food intake appears to be a secondary effect, and the result of a lack of need of energy for growth, since the kittens stop growing and slowly lose weight. Cats may be a good model for strict carnivores since it could be argued ideologically that strict carnivores that eat only animal tissue would never experience an essential amino acid deficiency. Therefore, carnivores do not need to respond in such a sensitive way to a protein or an essential amino acid deficiency as omnivores and herbivores. There is less evidence for dogs. It appears, however, that dogs may respond more like other omnivores (Milner, 1979a,b).

Omnivores and herbivores avoid diets deficient in a single essential amino acid. Rats are able to select between diets that contains less than 0.1 g/kg difference in an essential amino acid (Hrupka et al., 1997). Hrupka et al. (1999) also showed that the learned taste aversion that mediates this choice against a low dietary concentration of a particular essential amino acid occurs before food intake is decreased. That is, the establishment of a learned taste aversion is more sensitive to a deficiency than simply a reduction of food intake. Little work has been done on whether learned aversions occur after feeding various essential amino acid-deficient diets to dogs and cats. Dogs are known to select for an adequate quantity of protein (three to four times their requirement; Romoso and Ferguson, 1983; Torres et al., 2005), whereas cats do not (Cook et al., 1985).

Digestibility and Bioavailability of Protein and Amino Acids

Digestion of dietary protein by animals involves enzymatic cleavage of the protein into amino acids and small peptide residues that are capable of being absorbed by the mucosal cells of the small intestine. Protein digestibility—or more specifically, total digestive tract digestibility—is generally defined in nutritional science as the percentage of ingested protein that is not excreted in the feces as measured by input and output of nitrogen. Bioavailability is generally defined as the degree to which an ingested nutrient in a particular source is absorbed in a form that can be utilized in the animal’s metabolism (Lewis and Bayley, 1995). Much detailed work has been done on the bioavailability of amino acids from common proteins in food-animal nutrition (Lewis and Bayley, 1995; Sibbald, 1987) using ileal digestibilities as a measure of bioavailability. Similar studies have been done with dogs (see Johnson et al., 1998; Bednar et al., 2000; Clapper et al., 2001); however, almost nothing is available for cats (Hendriks and Emmens, 1998; Larsen et al., 2001, 2002), perhaps because of the perceived difficulty in keeping ileally cannulated cats (Mawby et al., 1999).
The first approach in determining bioavailability is to measure “apparent digestibility” of protein in a diet. This provides an overall evaluation of nitrogen absorbed but does not provide a measure of the “quality” or efficiency of utilization of nitrogen or of the individual essential amino acids. Historically, in human and animal nutrition, protein quality tests such as protein efficiency ratio (PER), biological value (BV), and net protein utilization (NPU), as determined in rat assays, have been used as one measure of overall amino acid bioavailability. Net protein utilization provides a measure of the efficiency of utilization of a protein. Differences in efficiencies of utilization of the same protein in various species may result from different digestibilities and/or nitrogen and amino acid requirements. Carnivores in general, including cats, have lower apparent digestibilities of poorly digestible proteins (Kendall et al., 1982; Ahlsrom and Skrede, 1998) and higher requirements for some amino acids such as arginine (Anderson et al., 1979a; Costello et al., 1980). Further refinement of the bioavailability values for individual amino acids results from determination of the ileal digestibility of individual essential amino acids. Although these values provide a better indication of bioavailability than total gastrointestinal (GI) tract digestibility, dietary protein could be 100 percent digested and absorbed, but protein and amino acids would still enter the colon because of gastrointestinal secretions (smeared mucosa and digestive enzymes). Thus, “true” ileal digestibilities have been measured using a number of techniques to estimate endogenous protein excreted from the ileum (Moughan et al., 1998). Since only some of this endogenous protein is essential for protein utilization, even true digestibilities of nitrogen and essential amino acids may not reflect true bioavailabilities. It should be noted that some dietary proteins contain inhibitors of trypsin or other enzymes that can greatly increase the loss of secreted enzymes. Generally, some in vivo measure, such as weight gain and/or nitrogen retention, is considered the ultimate or “gold standard” for determining nitrogen and amino acid bioavailabilities (Lewis and Bayley, 1995).

The apparent total tract digestibility of protein is similar in rats, cats, and dogs for highly digestible proteins. Proteins with lower digestibilities have higher apparent digestibilities in dogs than in cats (Kendall et al., 1982). For proteins with digestibilities greater than 90 percent (e.g., fresh mince and purified diets), there is no difference in digestibility between dogs and cats. For dry or canned dog or cat foods, dogs have a protein digestibility about 5-8 percent higher than do cats (Kendall et al., 1982). This difference in digestibility of protein in processed foods appears to be the result of the shorter length of the small intestine, relative to body size, in cats compared to dogs. Animal proteins generally have a higher digestibility than do plant proteins (Meyer et al., 1981, 1989; Kendall and Holme, 1982; Neimisch et al., 1991), and prolonged heat processing decreases animal protein digestibility by dogs and cats (Meyer et al., 1981; Backus et al., 1998; Johnson et al., 1998). Heat processing increases the digestibility of some proteins because antiproteolytic activity is destroyed by heat (Morgan et al., 1951). The digestibility of protein varies with size, breed, and age of dogs. Pointers had a higher apparent total tract digestibility of protein than huskies (85 vs. 81 percent), and young miniature poodles or schnauzers had a higher digestibility (about 4 percent higher) than did older ones (Hannah et al., 1995). Insoluble fiber is not reported to affect protein digestibility, whereas soluble fiber often decreases the total tract protein digestibility in both dogs (Muir et al., 1996; Silvio et al., 2000) and cats (Sunvold et al., 1995; Harper, 1996).

Digestibilities of the protein in various ingredients of typical dog food by ileally cannulated dogs have shown that the apparent ileal digestibility of crude protein (CP) is about 1-20 percentage units lower than apparent total tract digestibility. Presumably, bacteria degrade and utilize protein in the colon, with the release and absorption of ammonia and other low-molecular-weight nitrogen-containing compounds (Mühlum et al., 1988; Muir et al., 1996; Murray et al., 1997, 1998; Hendriks and Räth, 2002). Ileal crude protein digestibilities ranged from 63 to 96 percent whereas total tract protein digestibilities ranged from 71 to 98 percent. When diets contained a high content of low-digestible carbohydrate, ileal apparent protein digestibility was even more impaired than total tract digestibility (Mühlum et al., 1989). Ileal digestibilities of individual amino acids from normal ingredients in dog foods have been shown to vary tremendously (Johnson et al., 1998). True ileal digestibilities for some amino acids such as arginine varied from 77 to 87 percent, whereas others such as cystine, threonine, and lysine varied from 29 to 66 percent, 52 to 78 percent, and 62 to 84 percent, respectively. The lowest amino acid digestibilities were reported for rendered lamb meal, presumably because of extended heating during the rendering and drying process. For all of the essential amino acids, digestibilities of low-ash meat and bone meal were lower (5-18 percentage units) than those of high-ash meat and bone meal. The same was not true for poultry by-product meals for which no difference was found between high- and low-ash meals. Of particular interest is the very low cystine digestibility (29 percent) found in low-ash lamb meal and the finding that, in general, meat and bone meals had higher digestibilities of all of the essential amino acids than did poultry by-product meals. These results indicate the importance of quality control in processing ingredients (i.e., the need to control the rendering and drying processes to preserve a high digestibility of amino acids, especially cystine, threonine, and lysine). Surprisingly, the digestibility of methionine was not as low in this study, varying only from 83 to 93 percent (Johnson et al., 1998). Fiber content of the diet had little effect on ileal digestibility of crude protein except for soluble dietary fibers such as pectin (Meyer et al., 1989; Muir et al., 1996; Silvio et al., 2000). Addition of 50 g pectin kg⁻¹ diet caused a decrease of about 7 percent in ileal,
but only 2 percent in total tract crude protein digestibility (Muir et al., 1996). Good-quality soybean meal (properly heat treated) as an ingredient in dog food has equal or higher ileal and total tract digestibilities than good-quality meat meals (Bednar et al., 2000; Clapper et al., 2001), and the content of various carbohydrates including oligosaccharides in soybean meal had no significant effect on ileal digestibility of soybean protein (Meyer et al., 1989; Zuo et al., 1996). Johnson et al. (1998) compared digestibilities of dog food determined with cecotomized roosters to that with ileally cannulated dogs and found correlation coefficients of 0.89, 0.94, 0.87, and 0.90 for lysine, cystine, threonine, and methionine, respectively. Thus, apparent digestibilities determined by cecotomized roosters may be reasonable approximations for the bioavailability of amino acids for dogs. Larsen et al. (2001, 2002) reported validation of a growth assay to determine bioavailabilities of lysine and methionine in proteins for growing kittens. They showed that weight gain was 25 percent lower when kittens were given a casein diet (moistened, 50 g glucose/kg\(^{-1}\) casein, heated at 121°C for 2 hours) than when they were given a diet of non-heat-processed casein. Lysine in the casein before heat treatment had a bioavailability of 96 percent, whereas heat processing with glucose decreased its bioavailability to 56 percent. Since total tract protein digestibilities for the same food are lower in cats than in dogs (Kendall et al., 1982), it is doubtful that the rat or other rodent species will be satisfactory as a model for cats (Hendriks and Emmens, 1998).

Assessing Protein and Amino Acid Status

Long-term protein status can be assessed by the maintenance of serum albumin and lean body mass. Examination of concentrations of amino acids in plasma provides a basis for determining which amino acids may be limiting (Zicker and Rogers, 1996) in a particular diet. Acute protein deficiency with adequate intake of energy (e.g., very low protein or protein-free diet) causes a decrease in all amino acids in plasma. In long-term protein deficiency (protein-energy malnutrition), the concentrations of both serum albumin and the essential amino acids (except histidine and phenylalanine) plus tyrosine and cyst(e)ine are much lower than normal, and the dispensable amino acids (especially proline, alanine, serine, and glycine) are higher than normal (Holt et al., 1963). Since changes in concentrations of glycine and valine are most extreme after feeding a very low protein diet, the extent of distortion of the normal glycine-valine ratio has been used as an index of the severity of protein malnutrition. The only known cause of this unique pattern is protein-energy malnutrition. Food deprivation will not produce this pattern but will sustain a more normal amino acid pattern in plasma. If only the glycine-valine ratio is used for a nutritional diagnosis of dogs or cats with kidney disease, a false diagnosis of protein malnutrition may occur. In kidney disease, glycine increases in plasma because the kidney normally converts glycine to serine. However, dogs and cats are often anorexic during renal disease; so, some protein deficiency is not unusual.

Longenecker and Hause (1959) showed that even if dogs were not deficient in protein, the limiting dietary amino acid (and sometimes the second and third limiting) could be determined from the pattern of plasma amino acids. The essential amino acid that decreases the most (or increases the least), as a percentage, after feeding a complete meal containing the protein in question is the one that is most limiting; the one that decreases the next most is second limiting and so forth. This technique requires overnight food deprivation and the ingestion of a large meal. It is important to note that amino acids tend to return to normal if the animal is food deprived. Alternatively, plasma samples from dogs or cats fed a diet ad libitum for several days and taken in the absorptive phase provide the same information. For example, Hardy et al. (1977) reported that plasma valine decreased markedly when valine was limiting in the diet, from more than 300 nmol·m\(^{-1}\)·l\(^{-1}\) to 66 nmol·m\(^{-1}\)·l\(^{-1}\) at the requirement and to 33 nmol·m\(^{-1}\)·l\(^{-1}\) when valine was left completely out of the diet. Reference data generated in this way are useful to determine whether the need for each essential amino acid has been met. Rogers, Morris, and coworkers have determined the dose-response curve of each essential amino acid during amino acid requirement studies. These data—the concentration of each essential amino acid in plasma after feeding normal diets (adequate intake [AI], i.e., at least 1.5 times the minimum requirement [MR]); the concentration after feeding diets devoid of each essential amino acid (AA); the concentration after feeding diets containing each amino acid just at the MR; and for some amino acids, where present at a great excess (upper limit of tolerance or safe upper limit [SUL]) (Table 6-1)—can be used to determine the essential amino acid adequacy of diets for cats at various life stages. Unfortunately, similar complete plasma amino acid data are not available for dogs. Normal plasma amino acid concentrations are available (Strombeck and Roger 1978; Delaney et al., 2003), and some information is available for arginine, leucine, lysine, phenylalanine, and tyrosine for dogs (Tables 6-2A and B).

REQUIREMENTS, ALLOWANCES, AND TOLERANCES OF PROTEIN AND AMINO ACIDS

Role of Metabolic Adaptation in Protein and Amino Acid Nutrition

Relevant to both crude protein and essential amino acid requirements in various species is the nature and extent of metabolic adaptation in nitrogen and amino acid metabolism. For example, rats can down-regulate nitrogen catabolic enzymes to such an extent that they maintain nitrogen balance when fed a diet containing 4-5 percent of metabolizable energy (ME) as protein (National Research Coun
1985). Rats can also down-regulate the lysine catabolic pathway such that the lysine requirement for maintenance is only 12 percent that for growth, whereas the lack of specific down-regulation of isoleucine degradation enzymes results in an isoleucine requirement for maintenance 50 percent that for growth. The same detailed information is not available for dogs or cats; however, it is known that neither is as efficient in down-regulating nitrogen catabolism enzymes as rats (Rogers et al., 1977; Morris et al., 2002). Herbivores and omnivores in general show up- and down-regulation of nitrogen catabolism enzymes and of enzymes involved in the first irreversible step in the catabolism of essential amino acids. For the disposal and conservation of nitrogen, these adaptations particularly involve the up- and down-regulation of all of the urea cycle enzymes (Schnake, 1962), as well as alanine aminotransferase and aspartic aminotransferase (Kaplan and Prot, 1970). Changes in the flux through the urea cycle occur without a change in the amount of enzymes as a result of the following:

1. Increasing or decreasing the concentration of substrate. Increasing or decreasing the concentration of alanine, aspartic acid, glutamine, and glumatic acid will affect the flow of nitrogen from these and other amino acids into urea since most of the catalytic enzymes are working with substrate concentrations considerably below their Michaelis constant ($K_m$) values.

2. Changes in the concentration of ornithine in the liver. As the posthepatic state approaches and ammonia coming from the amino acids decreases or after feeding a

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### TABLE 6-1: Plasma Amino Acid Concentrations (mmol·L⁻¹) of Kittens

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>AA⁺⁺</th>
<th>AA⁻⁻</th>
<th>AA⁻⁻⁻</th>
<th>SUL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>42</td>
<td>55</td>
<td>100</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Histidine</td>
<td>8</td>
<td>70</td>
<td>75</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Leucine</td>
<td>22</td>
<td>25</td>
<td>75</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Lysine</td>
<td>45</td>
<td>60</td>
<td>100</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Methionine</td>
<td>11</td>
<td>25</td>
<td>75</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>11</td>
<td>25</td>
<td>75</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>10</td>
<td>25</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Threonine</td>
<td>10</td>
<td>25</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Valine</td>
<td>9</td>
<td>25</td>
<td>50</td>
<td>75</td>
</tr>
</tbody>
</table>

### TABLE 6-2B: Plasma Amino Acids Concentrations (mmol·L⁻¹) from Normal, Small-, and Large-Breed Adult Dogs (n = 151) Fed a Variety of Commercial Diets Known to Be Adequate for Maintenance

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Mean</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alanine</td>
<td>88</td>
<td>9.6</td>
</tr>
<tr>
<td>Arginine</td>
<td>103</td>
<td>2.6</td>
</tr>
<tr>
<td>Asparagine</td>
<td>40</td>
<td>3.1</td>
</tr>
<tr>
<td>Aspartate</td>
<td>47</td>
<td>1.9</td>
</tr>
<tr>
<td>Cysteine</td>
<td>47</td>
<td>3.3</td>
</tr>
<tr>
<td>Glutamine</td>
<td>23</td>
<td>1.2</td>
</tr>
<tr>
<td>Glutamate</td>
<td>99</td>
<td>9.4</td>
</tr>
<tr>
<td>Glycine</td>
<td>266</td>
<td>8.4</td>
</tr>
<tr>
<td>Proline</td>
<td>113</td>
<td>4.6</td>
</tr>
<tr>
<td>Hydroxyproline</td>
<td>67</td>
<td>4.1</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>51</td>
<td>1.3</td>
</tr>
<tr>
<td>Leucine</td>
<td>120</td>
<td>2.2</td>
</tr>
<tr>
<td>Lysine</td>
<td>132</td>
<td>3.0</td>
</tr>
<tr>
<td>Methionine</td>
<td>77</td>
<td>1.6</td>
</tr>
<tr>
<td>Ornithine</td>
<td>15</td>
<td>1.5</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>45</td>
<td>0.9</td>
</tr>
<tr>
<td>Proline</td>
<td>266</td>
<td>8.2</td>
</tr>
<tr>
<td>Serine</td>
<td>197</td>
<td>2.6</td>
</tr>
<tr>
<td>Threonine</td>
<td>77</td>
<td>2.1</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>178</td>
<td>5.6</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>50</td>
<td>1.7</td>
</tr>
<tr>
<td>Valine</td>
<td>187</td>
<td>4.1</td>
</tr>
</tbody>
</table>

**Note:** SEM = standard error of the mean.


---

**Table 6.2A:** Plasma Amino Acid Concentrations (mmol·L⁻¹) of Puppies

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>AA⁺⁺</th>
<th>AA⁻⁻</th>
<th>AA⁻⁻⁻</th>
<th>SUL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>25</td>
<td>72</td>
<td>125</td>
<td>—</td>
</tr>
<tr>
<td>Leucine</td>
<td>8</td>
<td>70</td>
<td>125</td>
<td>—</td>
</tr>
<tr>
<td>Lysine</td>
<td>35</td>
<td>55</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>35</td>
<td>65</td>
<td>100</td>
<td>—</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>40</td>
<td>70</td>
<td>125</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note:** SUL = standard deviation of the mean.

**Source:** Prepared by Crystal Springs Consulting, Inc.
low-protein diet, ornithine concentration in the liver decreases (as a result of the activity of ornithine -aminotransferase) and with very little acceptor available for carbamoyl phosphate, urea synthesis markedly decreases. After ingestion and absorption of arginine (usually in dietary protein) and the action of liver arginase, the liver is provided with sufficient ornithine to maximize urea synthesis for any particular activity of the urea cycle enzymes. If ornithine is limiting in the liver and a nitrogen source free of or low in arginine is given to an animal (Wergedal and Harper, 1964), hyperammonemia occurs. Cats (Morriss and Rogers, 1978a,b) are more sensitive to arginine deficiency than dogs (Burns et al., 1981; Czarnecki and Baker, 1984), which, in turn, are more sensitive than rats (Milner et al., 1975; Rogers, 1994).

3. Allosteric regulation of carbamoyl phosphate synthase. The first step in the synthesis of urea occurs via activation by N-acetylglutamate (NAG). Synthesis of NAG is allosterically regulated by arginine. Thus, although the $K_s$ of NAG synthase for arginine is five times higher in cats than in rats, the concentration of arginine in liver, as well as the precursors of NAG (glutamate and acetyl coenzyme A), influence hepatic NAG concentrations (Stewart et al., 1981). Both arginine and glutamate increase rapidly in liver after the intake of a high-protein meal, enhancing the ability of the liver to dispose of excess nitrogen. As substrates for urea synthesis decrease, NAG diffuses out of the mitochondria and is cleaved by an acetylase.

4. Up- and down-regulation of the nitrogen catabolic enzymes. The final level of control to enable the animal to maintain amino acid homeostasis is the up- and down-regulation of the nitrogen catabolic enzymes. This regulation can occur by changing the rate of degradation of the enzymes or, more generally, by changing the rate of synthesis of the enzymes through increasing the rate of synthesis of mRNA. Up- and down-regulation of the nitrogen catabolic enzymes does not appear to occur to any great extent in the cat (Rogers et al., 1977; Tews et al., 1984) and occurs to a lesser extent in the dog (Morriss et al., 2002) than in the rat. The three levels of control mentioned above are all rapid, occurring in seconds, whereas the changes in the amounts of the enzymes take 1-5 days. It appears that the extent to which animals can up- and down-regulate the amounts of the nitrogen catabolic enzymes is what really dictates the ability, on the one hand, to efficiently utilize high-protein diets, and, on the other, to be able to maintain nitrogen balance when fed a low-protein diet. Thus, it has been suggested that the high-protein requirement of adult cats at maintenance is the result of the inability to effectively down-regulate the hepatic nitrogen catabolic enzymes (Rogers et al., 1977). This interpretation has been challenged by Russell et al. (2002) using respiration calorimetry to measure protein oxidation in adult cats; they showed that cats fully oxidized all of the protein after adaptation to a normal (350 g kg$^{-2}$) and a high (520 g kg$^{-2}$) crude protein diet. These authors suggest that it is still unknown how the cats adapted to these two levels of protein, whereas Rogers and Morris (2002) contend that the first three levels of control described above, together with an increase in liver size (thereby increasing the total hepatic nitrogen catabolic enzymes), are sufficient to provide for complete oxidation of the relatively high quantities of dietary protein tested. Russell et al. (2002) did not address the inability of the cat to adapt to low-protein diets. Regardless of the interpretation of the results of these two groups, studies of the requirement for maintenance of adult cats show the lack of ability of cats to maintain nitrogen balance at the same minimal dietary concentration as dogs and the inability of dogs (at least long term) to maintain nitrogen balance at the same low concentration as that of rats.

The limited information available on the effect of dietary protein on amino acid metabolism (Primal et al., 1986; Humbert et al., 2002) and the adaptation of enzymes involved in the first step of the degradation of the essential amino acids (as well as important dispensable amino acids such as tyrosine and cystine) indicate some up- and down-regulation of these enzymes in the cat, but not to the same extent as in rats. For enzymes involved in the metabolism of tryptophan (Leklem et al., 1969), histidine (Rogers et al., 1977), methionine (Fau et al., 1987a, Striker, 1991), threonine (Hammer et al., 1996b), tyrosine (Bai et al., 1998), cysteine (Park et al., 1999), and taurine transport (Park et al., 1989), only about a 20-120 percent increase in activity occurs in cats switched from a low- to a high-protein diet, compared to a severalfold increase of these enzymes in rats. For example, threonine catabolic enzymes increase only about twofold when cats are switched from a low- to a high-protein diet (Hammer et al., 1996b), whereas under similar conditions, better than a tenfold increase occurs in rats (Freedland and Avery, 1964; Harper, 1968). Likewise, diet-induced daily rhythms as a result of eating a normal diet cause only a slight change (about 35 percent) in hepatic tyrosine aminotransferase activity of cats (Bai et al., 1998), whereas in rats a four- to five-fold change occurs (Wurtman and Axelrod, 1967). The consequence of less metabolic adaptation in dogs and cats is that even after adapting to a high-protein diet, plasma amino acid concentrations are higher after a meal (Tews et al., 1984; Torres and Rogers, 2002), whereas in rats after adaptation, plasma amino acids are similar whether they are adapted to a low- or a high-protein diet (Anderson et al., 1968).

Nitrogen (Crude Protein) Minimum Requirements, Recommended Allowances, and Adequate Intakes

Variables Used in Assessing Protein and Amino Acid Requirements

Nitrogen Balance

Nitrogen balance has, for many decades, been the preferred dependent variable for determining nitrogen and
Protein and Amino Acids

Amino acid requirements for all life stages. Often, there is no difference in the breakpoints for weight gain or nitrogen retention to determine individual amino acid requirements for growth of many species. Nevertheless, there are situations (and certain requirements) in which for dogs and cats, the breakpoint for nitrogen balance results in a higher requirement than that for weight gain. However, determination of the nitrogen requirement of cats, a clear plateau does not always occur (Hammer et al., 1996a), but, after the breakpoint, there is still a significant positive slope. Although maximal nitrogen retention has been the standard variable used, when determining the nitrogen requirement, it has been shown that apparent nitrogen balance for maintenance may be sustained while lean body mass is decreasing, apparently because of the low sensitivity and consistent errors in a positive direction for nitrogen retention that do not exist for the usual determinations of lean body mass (Hannah and Lattamne, 1996). In some experiments, only weight gain has been used; in others, both weight gain and nitrogen balance or just nitrogen balance (e.g., for maintenance). In still others, some other metabolic or physiological variable was used. In reviewing the literature on nitrogen and amino acid requirements, the variable that resulted in the highest MR was used.

Growth

The crude protein requirements for growing puppies and kittens have been determined primarily by using weight gain and nitrogen balance as the dependent variable. Mixed-food proteins have been used in practical diets, and purified proteins or free amino acids have been used in purified diets. Many experiments were done before the individual essential amino acid requirements were known for either of these species. There do appear to be any detrimental effects (except a slightly lower growth rate) of feeding diets at or slightly below the nitrogen requirement, provided all of the essential amino acid requirements are met for all functions known besides growth of muscle tissue and other structural body proteins (e.g., sufficient arginine for optimal urea cycle function, sufficient histidine to prevent cataracts). Under these conditions, if energy intake is restricted along with protein, there may be an increase in longevity in some breeds of dogs due to a delay in onset of chronic diseases (e.g., arthritis and insulin resistance) (Keely et al., 2002).

Maintenance, Gestation, and Lactation

Satisfactory maintenance can be achieved using a wide variety of dietary crude protein concentrations for adult cats on purified diets and diets using common feed ingredients. Cats, as compared to dogs, rats, and many herbivores or omnivores, do not show effective adaptation to low-protein diets and, thus, excrete considerably more nitrogen when fed a protein-free diet (Hendricks et al., 1997) or when food deprived (Bisorge et al., 1994). A comparison of obligatory nitrogen excretion in various species is shown in Table 6-3. It is apparent that the obligatory nitrogen loss in cats is similar whether adult cats were fed a protein-free diet or were food deprived, the loss being nearly twice that of dogs, while the loss in dogs is more than three times that of humans. These data support the fact that cats have a higher nitrogen requirement than these other species. The efficiency of utilization (e.g., NPU; Janssen et al., 1975) of protein for maintenance and growth is also lower in cats than in these other species. This appears to be the result of lack of ability to conserve both nitrogen and essential amino acids even though, on a relative basis, the nitrogen requirement is higher than that for the essential amino acids.

The protein requirements for reproduction of dogs or cats have not been studied extensively and, therefore, have not been well defined. General observations in both species indicate that the crude protein requirement and amino acid requirements for gestation do not exceed those found for maximal nitrogen retention of weanling puppies or kittens, whereas the requirement for maximal lactation is known to exceed that for maximal weight gain of weanling puppies and kittens.

Application of Variables to Assess Requirements

The most common variables found in reviewing the literature for crude protein and amino acid requirements of dogs and cats at various life stages were weight gain for growing animals and nitrogen balance for adult animals. In this section, the variables that result in the maximum requirement are used. Most often, a metabolic variable, such as minimizing urinary orotic acid for the arginine requirement or maximizing blood hemoglobin for the histidine requirement, gave the highest value. Often data on response to variable dietary concentrations were not available, especially for maintenance, gestation, and lactation. Therefore, for each amino acid, an adequate intake (AI) was estimated for the life stage from the quantity of each amino acid in the digestible protein of commercial, dry diets that were known to support normal maintenance, growth, and reproduction. Successful growth and reproduction of dogs and cats fed

Table 6-3: Endogenous Urinary Nitrogen Excretion of Animals Fed a Protein-Fed Diet

<table>
<thead>
<tr>
<th>Animal</th>
<th>mg N/kg 0.73 d⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>62</td>
</tr>
<tr>
<td>Marmoset</td>
<td>110</td>
</tr>
<tr>
<td>Rat</td>
<td>128</td>
</tr>
<tr>
<td>Pig</td>
<td>163</td>
</tr>
<tr>
<td>Dog</td>
<td>210</td>
</tr>
<tr>
<td>Cat</td>
<td>360</td>
</tr>
</tbody>
</table>

Source: Taken from Hendricks et al. (1997).
such diets over a period of several years are common. When requirement data were not available, these estimated AIs were also used as the recommended allowances.

**Growth**

**Dogs**

Estimates of the nitrogen requirement of growing puppies go back many decades. Summaries in the National Research Council (NRC) Nutrient Requirements series for dogs for crude protein, as a percentage of energy, in 1953, 1962, 1972-1974, and 1985 were, respectively, 200, 220, 220, and 85-115 g kg⁻¹ diet. There is general consistency in the recommended crude protein requirement across the decades except the 1985, which is the sum of the amino acids suggested (including the dispensable amino acids). It becomes apparent from the review by the 1985 NRC committee and from reviewing the literature over the past 20 years that there is a marked decrease in the requirements for both nitrogen and essential amino acids between about 10 and 14 weeks of age for growing puppies; thus, different requirements for weanling puppies before and after 14 weeks of age are suggested. Also, in some instances, weight gain, rather than nitrogen balance, has been used as the variable to determine the requirement. For dogs, generally more dietary crude protein is required for maximal nitrogen retention than for maximal weight gain. For newly weaned small- or large-breed puppies, when near maximal weight gains were obtained, the MR appears to be a 180 g CP kg⁻¹ diet containing 4.0 kcal ME g⁻¹ (Millner, 1981; Burns et al., 1982; Nap et al., 1993; Schaeffer et al., 1989; Delaney et al., 2001). These studies used either highly digestible protein or free amino acid diets, and all of the known essential amino acid requirements were met for maximal nitrogen retention. When practical diets from cereals and various animal by-products are used, the crude protein needed for maximal nitrogen retention (AI) appears to be about 250 g kg⁻¹ diet (Ornko et al., 1957; Case and Czarnecki-Maulden, 1990). For puppies over 14 weeks of age, the respective crude protein requirements (MR) for purified highly digestible diets and practical diets (AI) are, respectively, 140 and 200 g kg⁻¹ diet containing 4.0 kcal ME g⁻¹ (Gessert and Phillips, 1956; Burns et al., 1982; Delaney et al., 2001).

**Cats**

Several estimates have been made of the nitrogen requirement of growing kittens. The earliest estimates, determined without considering the essential amino acid requirements, were about 250-350 g of dietary crude protein per kilogram of diet (Dickinson and Scott, 1956; Miller and Allison, 1958; Greaves, 1965; Jansen et al., 1975). More recent estimates, based on dose-response curves in which protein or amino acid diets were used that contained all of the essential amino acids at least 50 percent above the requirements as listed by the NRC (1986), reported crude protein requirements in the range of 160-240 g kg⁻¹ diet containing 4 kcal ME g⁻¹ (Anderson et al., 1980; Small et al., 1985; Rogers et al., 1987). In a series of papers, Taylor and co-workers (1996, 1997, 1998) examined the pattern of amino acids required for maximal weight gain and nitrogen retention by growing kittens, varying both the concentration of crude protein in the diet and the ratio of essential amino acid nitrogen to total amino acid nitrogen (E:T). At or below the essential dietary amino acid requirements, the addition of crude protein (as dispensable amino acids) caused a decrease in weight gain and nitrogen retention that was corrected by additional arginine supplementation. If methionine and arginine were restricted to not more than about twice their requirements, optimal weight gains and nitrogen retention were observed, with all of the nitrogen coming from essential amino acids plus cystine and tyrosine. Kittens, therefore, can grow maximally (see Figure 6-1) with a much broader E:T ratio (Rogers et al., 1998; Taylor et al., 1998) than rats (Stucki and Harper, 1962) or chicks (Stucki and Harper, 1961). This work, using free amino acid diets and diets containing purified proteins (Small et al., 1985; Schaffer et al., 1989), indicates the minimum crude protein requirement (MR) for growth (with essential amino acids at about 150 percent of the 1986 NRC requirements) is about 180 g CP kg⁻¹ diet containing 4.0 kcal ME g⁻¹. The E:T ratio may vary widely at intermediate crude protein concentrations; however, the ratio has to be higher for similar weight gains at both low and high dietary crude protein concentrations (Figure 6-1). The E:T ratio must be high for low dietary crude protein concentrations in

![FIGURE 6-1. Effect of dietary crude protein and ratio of essential amino acid nitrogen to total amino acid nitrogen (E:T) on weight gain of kittens. SOURCE: Taken with permission from Rogers et al., 1998.](image-url)
order to provide all of the necessary essential amino acids (Taylor et al., 1997) and high at very high dietary crude protein concentrations to prevent toxicity of some dispensable amino acids such as glutamate. Glutamate is considerably more toxic when other dispensable amino acids are also high in the diet, presumably because metabolic equilibrium results in higher plasma and tissue glutamate concentrations (Taylor et al., 1998). Thus, for both low and high dietary protein concentrations, body weight gains are higher with high-quality than with low-quality proteins. Protein quality is less important at intermediate protein concentrations in the diet. In evaluating commercial, dry expanded diets that have sustained normal growth for growing kittens, none contained less than 280 g CP kg⁻¹ diet containing 4.0 kcal ME g⁻¹.

Maintenance

Dogs

Early estimates of the MR for crude protein for adult dogs at maintenance, using nitrogen balance as the criterion, varied from about 35 to 90 g kg⁻¹ diet containing 4.0 kcal ME g⁻¹ for good-quality proteins. These values came from experiments using food proteins without knowledge of the amino acid requirements for either growth or maintenance (Melnick and Cowgill, 1937; Kade et al., 1948; Arnold and Schad, 1954; Wannemacher and McCoy, 1966). Recently, Sanderson et al. (2001) published a study in which beagles maintained body weight (BW) and sustained normal blood chemistries and health (except for one dog that developed dilated cardiomyopathy, which was corrected by taurine supplementation) for 42-48 months with a diet calculated to be 82 g kg⁻¹ diet containing 4.0 kcal ME g⁻¹ as a highly digestible, high-quality protein. Except for the question about meeting the taurine need of the dogs, these results together with earlier work suggest 80 g of crude protein per kilogram of diet containing 4.0 kcal ME g⁻¹ as the MR. Other studies (Wannemacher and McCoy, 1966; Ward, 1976), published and unpublished, support an AI of about 100 g kg⁻¹ diet containing 4 kcal ME g⁻¹ as being adequate, thus suggesting 100 g CP kg⁻¹ diet as the RA. Older dogs appear to require somewhat more crude protein to maintain feline protein (so-called protein reserves), perhaps as much as 50 percent more (Wannemacher and McCoy, 1966). The optimal concentrations for other variables and outcomes (e.g., optimal immune response, wound healing, health in old age) have to be evaluated before more specific recommendations can be made.

Cats

Early estimates of the minimum crude protein requirement (or allowance) (MR) of adult cats for maintenance, using nitrogen balance as the criterion, varied from about 10 to 30 percent of ME. These values came from experiments using food proteins without knowledge of the amino acid requirements for either growth or maintenance (Allison et al., 1956; Miller and Allison, 1958; Geaves and Scott, 1960) or sometimes without considering the digestibility of the dietary proteins. The difficulty in making a purified diet readily acceptable to adult cats, often very choosy about the texture and taste of their food, has made determining the crude protein and amino acid requirements problematical. Indeed, in one of the most thorough, long-term studies reported, using nitrogen balance as the criterion in which the diet contained the essential amino acids at a dietary concentration at least equivalent to the essential amino acid requirements of the growing kitten, the crude protein requirement was suggested to be 125 g kg⁻¹ diet (100 g kg⁻¹ diet containing 4.0 kcal ME g⁻¹) (Burger et al., 1984; Burger and Smith, 1987). However, the authors removed some cats from the study because they would not accept the diet, and the cats as a whole lost a small amount of weight. Nitrogen balance is known to underestimate the nitrogen requirement because of incomplete collection of feces and spilled food. In most experiments with most species, there is a plateau at a small positive nitrogen balance. In the work of Burger et al. (1984), when the regression line crossed at 0 nitrogen balance, 7 of 18 cats fed 164 g CP kg⁻¹ diet were in negative nitrogen balance. With all but one cat in positive nitrogen balance, the protein intake was calculated to be about 160 g kg⁻¹ diet containing 4 kcal ME g⁻¹. This value is taken as the crude protein MR of adult cats for maintenance. It should be pointed out that other outcome variables such as optimizing immune response, labile tissue protein, or environmental stress were not considered in this MR. If a safety allowance is made for such needs, a recommended allowance (RA) of 200 g CP kg⁻¹ diet containing 4 kcal ME g⁻¹ is suggested. In evaluating commercial, dry, expanded diets that have sustained maintenance for months to years, none were found with less than 265 g CP kg⁻¹ diet containing 4.0 kcal ME g⁻¹.

Gestation and Lactation

Dogs

The protein and amino acid requirements of dogs during reproduction have not been well defined. In general, it has been assumed that, if the dietary crude protein requirement is met for growing puppies, the diet would meet the crude protein requirement of bitches during gestation and lactation. No reports could be found in which the crude protein requirement for gestation or lactation had been determined using dose-response relationships in bitches fed purified diets. From experimental work using natural ingredients (Visek et al., 1976) and evaluating commercial, dry dog foods that have routinely supported normal gestation and lactation, the AI for crude protein for gestation and lactation for the bitch has been shown to be 180-210 kcal g⁻¹ diet containing 4 kcal ME g⁻¹. Meyer et al. (1985) did a factorial cal-
culation based on experimental work on milk yield and milk composition of bitches and recommended 210 g CP·kg⁻¹ diet containing 4 kcal ME·g⁻¹, provided the protein quality was good and the diet contained carbohydrates. Based on their experimental work, they also calculated values of 10 g protein·kg⁻¹ BW⁻⁰·⁷⁵ for small bitches suckling two puppies, 20 g·kg⁻¹ BW⁻⁰·⁷⁵ for medium-sized bitches suckling six puppies, and 25 g·kg⁻¹ BW⁻⁰·⁷⁵ for large bitches suckling eight puppies. Romgos et al. (1981) evaluated reproduction with and without dietary carbohydrate using diets containing about 260 g·kg⁻¹ crude protein (180–210 g·kg⁻¹ digestible crude protein·kg⁻¹ at 4 kcal ME·g⁻¹) and showed that this concentration was ample protein for both gestation and lactation if the diet contained carbohydrate, whereas, if the diet contained no carbohydrate, 260 g CP·kg⁻¹ diet was insufficient for the latter part of gestation but was sufficient for lactation. Kienzle et al. (1985) showed that, when carbohydrate-free diets were fed to pregnant and lactating bitches, a protein content of 400 g·kg⁻¹ diet was sufficient for successful reproduction, but a protein content of only 200 g·kg⁻¹ diet led to severe impairment of reproduction including hypoglycemia in the bitch, high losses of puppies, low liver glycogen in the puppies, increased milk fat, decreased milk lactose and water content, and decreased milk yield. From the above results, the AURA for highly digestible crude protein for gestation and lactation is set at 200 g·kg⁻¹ diet containing 4.0 kcal ME·g⁻¹, provided there is carbohydrate in the diet.

Cats

The protein and amino acid requirements of queens during reproduction have not been well defined. It has been assumed that the dietary crude protein requirement for the growing kitten would meet the crude protein requirement of the queen during gestation and lactation. Factorial calculations by Kienzle (1998) of the protein requirements of queens during peak lactation indicated 210–290 g·kg⁻¹ diet containing 4 kcal ME·g⁻¹ was required. Pichota et al. (1995), using purified diets based on soybean protein-casein (supplemented with essential amino acids to bring each one to at least 150 percent of the 1986 NRC requirements for growth) reported the MR to be not greater than 170 g·kg⁻¹ diet containing 4 kcal ME·g⁻¹ for gestation and about 240 g·kg⁻¹ for lactation using kitten weight gain and queen weight loss during lactation as key variables. Thus, the MRs for crude protein for cats during gestation and lactation, respectively, are taken as 170 and 240 g·kg⁻¹ diet containing 4.0 kcal ME·g⁻¹. This requirement for lactation is consistent with the lowest level of digestible crude protein found in a number of dry, expanded, commercial diets that have regularly sustained gestation and lactation. From an evaluation of plasma amino acid results, the highest nutritional requirement appeared to be during peak lactation (third to fourth week), before the kitten’s intake of the queen’s diet was significant. When plasma amino acids were used as the criterion, several essential amino acids appeared to be near limiting, even with commercial diets containing 260 g·kg⁻¹ crude protein (4 kcal ME·g⁻¹). Methionine appeared to be the limiting amino acid most often, with the crude protein and amino acid requirements being higher for maximal lactation than for maximal growth of kittens.

Amino Acid Minimum Requirements, Recommended Allowances, Adequate Intakes, and Safe Upper Limits

Satisfactory maintenance and maximal growth and reproduction of dogs and cats can be achieved on a wide variety of concentrations of amino acids in purified diets using either free amino acids, amino acids in purified proteins, or proteins from common feed ingredient incorporated into dry expanded or canned diets; that is, no upper limit is known. The 10 amino acids shown to be essential for growing rats have been shown to be essential for growing dogs and cats. No studies have been reported in which the essential amino acids for other life stages have been deleted from the diet of either dogs or cats, except for the abstract of Rose and Rice (1939), which showed that all of the same amino acids that are essential for adult rats are essential for adult dogs. Later, Burns et al. (1981) reported that arginine was essential in the diet to prevent hyperammonemia and ornithic aciduria in the adult dog. Similar to other adult species, it is assumed all of the other amino acids essential for adult rats and humans are essential for adult dogs and cats.

Arginine

Some synthesis of arginine occurs in many mammals and at a sufficient rate to provide all of the arginine needs for a variety of species including humans, ruminants, and adult rats and swine (Rogers, 1994). Metabolically, arginine is glucogenic and has functions other than its role in the synthesis of innumerable proteins. Arginine is an intermediate in the urea cycle, and when absorbed with a meal, it acts both anaplerotically to stimulate urea synthesis and as an allosteric activator of acetylglutamate, which in turn, is an essential allosteric activator of carbamoyl-phosphate synthase, the first enzyme in the detoxification of ammonia and the synthesis of urea. In addition, arginine has been shown to elicit the release of several hormones and metabolic mediators including insulin, glucagon, and gastrin, and it is a precursor of biogenic amines, which are important in cell replication. Arginine is also the precursor of nitric oxide, the neurotransmitter involved in many systems, from its effect on blood pressure via relaxation of blood vessels to its role in macrophages in killing foreign cells (e.g., bacteria and viruses). There have been many studies using arginine as a therapeutic agent, apart from its role in normal nutrition and health. The committee’s recommendations are based on the need of dogs and cats to minimize urinary ornithic acid.
## Table 15-3 Nutrient Requirements for Growth in Puppies after Weaning

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Requirement</th>
<th>Breed</th>
<th>Age</th>
<th>Requirement</th>
<th>Breed</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein</td>
<td>15-20%</td>
<td>Small</td>
<td>Puppy</td>
<td>20-25%</td>
<td>Small</td>
<td>Puppy</td>
</tr>
<tr>
<td>Fat</td>
<td>10-15%</td>
<td>Small</td>
<td>Puppy</td>
<td>15-20%</td>
<td>Small</td>
<td>Puppy</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>30-40%</td>
<td>Small</td>
<td>Puppy</td>
<td>35-45%</td>
<td>Small</td>
<td>Puppy</td>
</tr>
</tbody>
</table>

Note: The table continues with similar detailed nutrient requirements for puppies of different breeds and ages.
TABLE 15-3 (continued)

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimal Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amt./kg DM</td>
<td>Amt./kg kcal</td>
<td>Amt./kg ME%</td>
<td>Amt./kg DM</td>
</tr>
<tr>
<td>Chloride (mg)</td>
<td>2,900</td>
<td>720</td>
<td>200</td>
<td>2,900</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>72</td>
<td>18</td>
<td>5.0</td>
<td>88</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>11</td>
<td>2.7</td>
<td>0.76</td>
<td>11</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>100</td>
<td>25</td>
<td>8.44</td>
<td>100</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>5.6</td>
<td>1.4</td>
<td>0.38</td>
<td>5.6</td>
</tr>
<tr>
<td>Selenium (ug)</td>
<td>210</td>
<td>52.5</td>
<td>13.7</td>
<td>350</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.212</td>
<td>303</td>
<td>84.5</td>
<td>15.15</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.0</td>
<td>0.25</td>
<td>0.76</td>
<td>1.0</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>1.5</td>
<td>0.38</td>
<td>0.84</td>
<td>1.5</td>
</tr>
<tr>
<td>Pantothenic Acid (mg)</td>
<td>1.5</td>
<td>0.38</td>
<td>0.84</td>
<td>1.5</td>
</tr>
<tr>
<td>Biotin*</td>
<td>1.3</td>
<td>0.38</td>
<td>0.84</td>
<td>1.3</td>
</tr>
<tr>
<td>Choline (mg)</td>
<td>1,360</td>
<td>340</td>
<td>95</td>
<td>1,700</td>
</tr>
</tbody>
</table>

*The values for Amt/kg DM have been calculated assuming a dietary energy density of 4,000 kcal ME/kg. (The term = signifies equivalence.) If the energy density of the diet is not 4,000 kcal ME/kg, then to calculate the Amt/kg DM for each nutrient, multiply the value for the nutrient in the column labeled Amt/kg DM by the energy density of the pet food (in kcal ME/kg) and divide by 4,000.

To calculate the amount to feed of each nutrient, multiply the value for Amt/kg kcal for each nutrient by the energy requirement for the puppy in kcal calculated from Table 15-2 and divide by 1,000.

The values for Amt/kcal apply only to 5.5-kg puppies of expected mature weight of 35 kg. To calculate the amount of a nutrient for puppies of different current or expected mature body weights, calculate the energy requirement from Table 15-2 and multiply this by the nutrient Amt/1,000 kcal and divide by 1,000.

For 4 to 14 week old puppies, 0.01 g arginine should be added for every g of crude protein above 180 g and 225 g, for the MR and RA, respectively, of arginine. For puppies over 14 weeks of age, 0.01 g arginine should be added for every g of crude protein above 180 g and 225 g for the MR and RA of arginine, respectively.

The quantity of tyrosine required to minimize black hair color may be about 1.5-2.0 times this quantity.

The requirement for ω-6-linoleic acid varies depending upon linoleic acid content of the diet. The ratio of linoleic acid to ω-6-linoleic acid should be between 2.6 and 16. Net of 0.8 g/kg DM value shown is the minimum RA of ω-6-linoleic acid at 13 g linoleic acid per kg DM, resulting in a ratio of linoleic acid to ω-6-linoleic acid of approximately 16.

Eicosapentaenoic acid should not exceed 60% of the total amount.

The RA for the calcium requirements of weaned puppies (of expected mature body weight 25 kg) for up to 14 weeks of life should not be less than 0.54 g calcium/kg body weight.

Some oxide forms of iron and copper should not be used because of low bioavailability.

For vitamin A, requirements are expressed as RE (retinol equivalents). One RE is equal to 1 μg of all-trans retinol, and one IU of vitamin A is equal to 0.3 RE. Safe upper limit values are expressed as μg retinol.

1 μg cholecalciferol = 40 IU vitamin D₃.

Higher concentrations of vitamin E are recommended for high PUFA diets. One international unit of vitamin E = 1 mg all-rac-α-tocopherol acetate (see Chapter 8).

Dogs have a metabolic requirement, but a dietary requirement has not been demonstrated when natural diets are fed. Adequate vitamin K is probably synthesized by intestinal microbes. The vitamin K allowance is expressed in terms of the commercially used precursor menadione that requires alkylation to the active vitamin K.

For normal diets not containing raw egg white, adequate biotin is probably provided by microbial synthesis in the intestine. Diets containing antibiotics may need supplementation.
### Table 15-4
Daily Metabolizable Energy Requirements for Adult Dogs at Maintenance

<table>
<thead>
<tr>
<th>Type</th>
<th>Kcal × kg DW$^{75}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for laboratory kennel dogs or active pet dogs$^a$</td>
<td>130</td>
</tr>
<tr>
<td>Above average requirements:</td>
<td></td>
</tr>
<tr>
<td>Young adult laboratory dogs or young adult active pet dogs</td>
<td>140</td>
</tr>
<tr>
<td>Adult laboratory Great Danes or active pet Great Danes</td>
<td>200</td>
</tr>
<tr>
<td>Adult laboratory terriers or active pet terriers</td>
<td>180</td>
</tr>
<tr>
<td>Below average requirements:</td>
<td></td>
</tr>
<tr>
<td>Inactive pet dogs$^a$</td>
<td>95</td>
</tr>
<tr>
<td>Older laboratory dogs or older active pet dogs or laboratory Newfoundlands</td>
<td>105</td>
</tr>
</tbody>
</table>

$^a$Dogs kept in a domestic environment with strong stimuli and ample opportunity to exercise, such as dogs in multiple dog households, in the country or in a house with a large yard.

$^b$Dogs kept in a domestic environment with little stimulus and opportunity to exercise. Requirements of older or overweight dogs may still be underestimated.

### Table 15-5
Nutrient Requirements of Adult Dogs for Maintenance

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Min. Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;4000 kcal</td>
<td>=&lt;4000 kcal</td>
<td>=&lt;4000 kcal</td>
<td>=&lt;4000 kcal</td>
</tr>
<tr>
<td></td>
<td>kcal/ME $^{75}$</td>
<td>kcal/ME $^{75}$</td>
<td>kcal/ME $^{75}$</td>
<td>kcal/ME $^{75}$</td>
</tr>
<tr>
<td></td>
<td>1.000 kg</td>
<td>1.000 kg</td>
<td>1.000 kg</td>
<td>1.000 kg</td>
</tr>
<tr>
<td>Crude Protein (g)</td>
<td>80 20 2.62</td>
<td>80 20 2.62</td>
<td>80 20 2.62</td>
<td>80 20 2.62</td>
</tr>
<tr>
<td>Amino Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine (g)</td>
<td>2.8 0.79 0.092</td>
<td>3.5 0.88 0.11</td>
<td>3.5 0.88 0.11</td>
<td>3.5 0.88 0.11</td>
</tr>
<tr>
<td>Histidine (g)</td>
<td>1.5 0.47 0.048</td>
<td>1.9 0.48 0.062</td>
<td>1.9 0.48 0.062</td>
<td>1.9 0.48 0.062</td>
</tr>
<tr>
<td>Isoleucine (g)</td>
<td>3.6 0.76 0.098</td>
<td>3.8 0.95 0.12</td>
<td>3.8 0.95 0.12</td>
<td>3.8 0.95 0.12</td>
</tr>
<tr>
<td>Methionine (g)</td>
<td>2.6 0.65 0.085</td>
<td>3.4 0.95 0.11</td>
<td>3.4 0.95 0.11</td>
<td>3.4 0.95 0.11</td>
</tr>
<tr>
<td>Methionine &amp; Cystine (g)</td>
<td>3.2 1.10 0.17</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
</tr>
<tr>
<td>Leucine (g)</td>
<td>2.4 1.25 0.18</td>
<td>3.4 1.08 0.14</td>
<td>3.4 1.08 0.14</td>
<td>3.4 1.08 0.14</td>
</tr>
<tr>
<td>Lysine (g)</td>
<td>2.8 0.70 0.092</td>
<td>3.8 0.95 0.12</td>
<td>3.8 0.95 0.12</td>
<td>3.8 0.95 0.12</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>3.6 0.60 0.042</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
</tr>
<tr>
<td>Phenylalanine &amp; Tyrosine (g)</td>
<td>3.9 1.48 0.19</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
<td>4.5 1.33 0.21</td>
</tr>
<tr>
<td>Threonine (g)</td>
<td>3.4 0.85 0.14</td>
<td>4.3 1.06 0.13</td>
<td>4.3 1.06 0.13</td>
<td>4.3 1.06 0.13</td>
</tr>
<tr>
<td>Tryptophan (g)</td>
<td>1.1 0.28 0.036</td>
<td>1.4 0.35 0.06</td>
<td>1.4 0.35 0.06</td>
<td>1.4 0.35 0.06</td>
</tr>
<tr>
<td>Valine (g)</td>
<td>3.9 0.68 0.11</td>
<td>4.4 1.27 0.17</td>
<td>4.4 1.27 0.17</td>
<td>4.4 1.27 0.17</td>
</tr>
<tr>
<td>Total Fat (g)</td>
<td>40 19 1.3</td>
<td>65 21 1.6</td>
<td>65 21 1.6</td>
<td>65 21 1.6</td>
</tr>
<tr>
<td>Fatty Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linoleic Acid (g)</td>
<td>9.6 2.4 0.3</td>
<td>11 2.8 0.58</td>
<td>11 2.8 0.58</td>
<td>11 2.8 0.58</td>
</tr>
<tr>
<td>γ-Linolenic Acid (g)</td>
<td>0.36 0.09 0.02</td>
<td>0.44 0.11 0.03</td>
<td>0.44 0.11 0.03</td>
<td>0.44 0.11 0.03</td>
</tr>
<tr>
<td>Arachidonic Acid (g)</td>
<td>0.44 0.11 0.03</td>
<td>0.44 0.11 0.03</td>
<td>0.44 0.11 0.03</td>
<td>0.44 0.11 0.03</td>
</tr>
<tr>
<td>Docosahexaenoic Acid (g)</td>
<td>0.8 0.18 0.02</td>
<td>0.8 0.18 0.02</td>
<td>0.8 0.18 0.02</td>
<td>0.8 0.18 0.02</td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (g)</td>
<td>2.0 0.48 0.089</td>
<td>3.0 0.75 0.10</td>
<td>3.0 0.75 0.10</td>
<td>3.0 0.75 0.10</td>
</tr>
<tr>
<td>Phosphorus (g)</td>
<td>1.0 0.18 0.03</td>
<td>2.0 0.40 0.07</td>
<td>2.0 0.40 0.07</td>
<td>2.0 0.40 0.07</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>100 25 0.13</td>
<td>100 25 0.13</td>
<td>100 25 0.13</td>
<td>100 25 0.13</td>
</tr>
</tbody>
</table>

(continued)
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimal Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Am. kg DM (b)</td>
<td>Am. kcal</td>
<td>Am. kg DM (b)</td>
<td>Am. kcal</td>
</tr>
<tr>
<td>Sodium</td>
<td>300</td>
<td>75</td>
<td>9.05</td>
<td>800</td>
</tr>
<tr>
<td>Potassium</td>
<td>4.0</td>
<td>1.0</td>
<td>0.14</td>
<td>4.0</td>
</tr>
<tr>
<td>Chloride</td>
<td>1,200</td>
<td>300</td>
<td>40</td>
<td>1,200</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>30</td>
<td>7.5</td>
<td>1.0</td>
<td>30</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>60</td>
<td>1.5</td>
<td>0.2</td>
<td>60</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>4.8</td>
<td>1.2</td>
<td>0.16</td>
<td>4.8</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>359</td>
<td>87.5</td>
<td>11.8</td>
<td>350</td>
</tr>
<tr>
<td>Selenium (µg)</td>
<td>700</td>
<td>175</td>
<td>23.6</td>
<td>700</td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>1,212</td>
<td>303</td>
<td>40</td>
<td>1,515</td>
</tr>
<tr>
<td>Cholecalciferol (µg)</td>
<td>11.0</td>
<td>2.75</td>
<td>0.36</td>
<td>13.8</td>
</tr>
<tr>
<td>Vitamin E (α-tocopherol) (mg)</td>
<td>24</td>
<td>6.0</td>
<td>0.8</td>
<td>24</td>
</tr>
<tr>
<td>Vitamin K (Menadione) (µg)</td>
<td>1.3</td>
<td>0.33</td>
<td>0.043</td>
<td>1.63</td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.8</td>
<td>0.45</td>
<td>0.059</td>
<td>2.25</td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>1.2</td>
<td>0.30</td>
<td>0.04</td>
<td>1.5</td>
</tr>
<tr>
<td>Pantothenic Acid (mg)</td>
<td>12.6</td>
<td>3.4</td>
<td>0.45</td>
<td>17.0</td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>13.6</td>
<td>3.4</td>
<td>0.45</td>
<td>13.6</td>
</tr>
<tr>
<td>Pantothenic Acid (mg)</td>
<td>12.6</td>
<td>3.4</td>
<td>0.45</td>
<td>13.6</td>
</tr>
<tr>
<td>Cobalamin (µg)</td>
<td>28</td>
<td>7</td>
<td>0.92</td>
<td>28</td>
</tr>
<tr>
<td>Folic Acid (µg)</td>
<td>216</td>
<td>54</td>
<td>7.1</td>
<td>216</td>
</tr>
<tr>
<td>Choline (mg)</td>
<td>1,340</td>
<td>340</td>
<td>45</td>
<td>1,700</td>
</tr>
</tbody>
</table>

*The values for Am. kg DM have been calculated assuming a dietary energy density of 4.000 kcal/kg. (The term kg signifies equivalence.) If the energy density of the diet is not 4.000 kcal/kg, then the calculation for Am. kg DM for each nutrient, multiply the value for the nutrient in the column labeled Am. kg DM by the energy density of the pet food (kcal kg ME/kJ) and divide by 4.000.

To calculate the amount to feed of each nutrient, multiply the value for Am. kg/1,000 kcal ME/kg for each nutrient by the energy requirement for laboratory dogs in kcal (calculated from Table 15-4) and divide by 1,000. For dogs with an unusually low energy intake (below the suggested requirements), the nutrient concentrations (Am. kg 1,000 kcal) may not be adequate. These animals should be fed the nutrient amounts shown in the column Am. kg DM.

0.01 g arginine should be added for every g of crude protein above 80 g and 100 g for the MR and RA, respectively.

The quantity of tyrosine required to maximize black hair color may be about 1.5-2.0 times this quantity.

The requirement for α-linolenic acid varies depending upon linoleic acid content of the diet. The ratio of linoleic acid to α-linolenic acid should be between 2.6 and 26. Note that 0.44 g/kg DM value shown is the minimum RA of α-linolenic acid at 11 g linoleic acid per kg DM, resulting in a ratio of linoleic acid to α-linolenic acid of approximately 25.

50-60% of the total amount should be eicosapentaenoic acid, and 40-50% should be docosahexaenoic acid.

Some oxides of iron and copper should not be used because of low bioavailability.

Vitamin A requirements expressed as RE (retinol equivalents). One RE is equal to 1 µg of all-rac retinol, and one IU of vitamin A is equal to 0.3 RE. Safe upper limit values expressed as µg retinol.

1 µg cholecalciferol = 40 IU vitamin D3.

Higher concentrations of vitamin E are recommended for high PUFA diets. One international unit of vitamin E = 1 mg all-rac-α-tocopherol acetate (see Chapter 8).

Dogs have a metabolic requirement, but a dietary requirement has not been demonstrated when natural diets are fed. Adequate vitamin K is probably synthesized by intestinal microbes. The vitamin K allowance is expressed in terms of the commercially used precursor menadione that requires alkylation to the active vitamin K.

For normal diets not containing raw egg white, adequate biotin is probably provided by microbial synthesis in the intestine. Diets containing antibiotics may need supplementation.
### Table 15-8: Nutrient Requirements of Bitches for Late Gestation and Peak Lactation

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimal Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg DM (1000 kcal)</td>
<td>kg (1000 kcal)</td>
<td>kg (1000 kcal)</td>
<td>kg (1000 kcal)</td>
</tr>
<tr>
<td>Crude Protein</td>
<td>200</td>
<td>30</td>
<td>24.6</td>
<td>200</td>
</tr>
<tr>
<td>Amino Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine (g)</td>
<td>10.0</td>
<td>2.50</td>
<td>1.23</td>
<td>0.0</td>
</tr>
<tr>
<td>Histidine (g)</td>
<td>4.4</td>
<td>1.16</td>
<td>0.54</td>
<td>4.4</td>
</tr>
<tr>
<td>Isoleucine (g)</td>
<td>7.1</td>
<td>1.78</td>
<td>0.87</td>
<td>7.1</td>
</tr>
<tr>
<td>Methionine (g)</td>
<td>3.1</td>
<td>0.78</td>
<td>0.38</td>
<td>3.1</td>
</tr>
<tr>
<td>Methionine &amp; Cystine (g)</td>
<td>6.2</td>
<td>1.53</td>
<td>0.76</td>
<td>6.2</td>
</tr>
<tr>
<td>Lysine (g)</td>
<td>20.0</td>
<td>5.00</td>
<td>2.46</td>
<td>20.0</td>
</tr>
<tr>
<td>Phenylalanine (g)</td>
<td>8.3</td>
<td>2.08</td>
<td>1.02</td>
<td>8.3</td>
</tr>
<tr>
<td>Phenylalanine &amp; Tyrosine (g)</td>
<td>12.5</td>
<td>3.08</td>
<td>1.51</td>
<td>12.5</td>
</tr>
<tr>
<td>Tyrosine (g)</td>
<td>10.4</td>
<td>2.60</td>
<td>1.28</td>
<td>10.4</td>
</tr>
<tr>
<td>Valine (g)</td>
<td>1.2</td>
<td>0.30</td>
<td>0.15</td>
<td>1.2</td>
</tr>
<tr>
<td>Total Fat (g)</td>
<td>13.6</td>
<td>3.25</td>
<td>1.60</td>
<td>13.6</td>
</tr>
<tr>
<td>Fatty Acids</td>
<td>85</td>
<td>21.3</td>
<td>10.5</td>
<td>85</td>
</tr>
<tr>
<td>Linoleic Acid (g)</td>
<td>11</td>
<td>2.8</td>
<td>1.4</td>
<td>11</td>
</tr>
<tr>
<td>α-Linolenic Acid (g)</td>
<td>0.7</td>
<td>0.18</td>
<td>0.09</td>
<td>0.7</td>
</tr>
<tr>
<td>Arachidonic Acid (g)</td>
<td>0.5</td>
<td>0.13</td>
<td>0.06</td>
<td>0.5</td>
</tr>
<tr>
<td>Docosahexaenoic Acid (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (g)</td>
<td>8.0</td>
<td>1.9</td>
<td>0.82</td>
<td>8.0</td>
</tr>
<tr>
<td>Phosphorus (g)</td>
<td>5.0</td>
<td>1.2</td>
<td>0.58</td>
<td>5.0</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>600</td>
<td>150</td>
<td>69</td>
<td>600</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>2,000</td>
<td>500</td>
<td>238</td>
<td>2,000</td>
</tr>
<tr>
<td>Potassium (g)</td>
<td>3.6</td>
<td>0.9</td>
<td>0.43</td>
<td>3.6</td>
</tr>
<tr>
<td>Chloride (mg)</td>
<td>3,000</td>
<td>750</td>
<td>358</td>
<td>3,000</td>
</tr>
<tr>
<td>Iron (mg)</td>
<td>70</td>
<td>17</td>
<td>8.67</td>
<td>70</td>
</tr>
<tr>
<td>Copper (mg)</td>
<td>12.4</td>
<td>3.1</td>
<td>1.52</td>
<td>12.4</td>
</tr>
<tr>
<td>Zinc (mg)</td>
<td>96</td>
<td>24</td>
<td>11.7</td>
<td>96</td>
</tr>
<tr>
<td>Manganese (mg)</td>
<td>7.7</td>
<td>1.9</td>
<td>1.8</td>
<td>7.7</td>
</tr>
<tr>
<td>Selenium (mg)</td>
<td>0.08</td>
<td>0.02</td>
<td>0.01</td>
<td>0.08</td>
</tr>
<tr>
<td>Iodine (μg)</td>
<td>880</td>
<td>220</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td>Vitamin A (RE)</td>
<td>1,212</td>
<td>303</td>
<td>149</td>
<td></td>
</tr>
<tr>
<td>Cholesterol (mg)</td>
<td>11.0</td>
<td>2.75</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>Vitamin E (α-tocopherol) (mg)</td>
<td>24</td>
<td>6.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Vitamin K (Menadione) (mg)</td>
<td>1.3</td>
<td>0.33</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>Thiamin (mg)</td>
<td>1.8</td>
<td>0.45</td>
<td>0.22</td>
<td></td>
</tr>
<tr>
<td>Riboflavin (mg)</td>
<td>4.2</td>
<td>1.05</td>
<td>0.52</td>
<td></td>
</tr>
<tr>
<td>Pyridoxine (mg)</td>
<td>1.2</td>
<td>0.30</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>Niacin (mg)</td>
<td>13.6</td>
<td>3.4</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>Pantothenic Acid (mg)</td>
<td>12</td>
<td>3.0</td>
<td>1.48</td>
<td></td>
</tr>
<tr>
<td>Cobalamin (μg)</td>
<td>28</td>
<td>7</td>
<td>3.45</td>
<td></td>
</tr>
<tr>
<td>Folic Acid (μg)</td>
<td>216</td>
<td>54</td>
<td>26.6</td>
<td></td>
</tr>
<tr>
<td>Choline (mg)</td>
<td>1,360</td>
<td>340</td>
<td>167</td>
<td></td>
</tr>
</tbody>
</table>

*Few data could be found for the dietary concentrations for the minimal requirement for gestation for the bitch. The values for lactation relative to kg DM and 1,000 kcal ME may be taken as satisfactory for gestation.*

*The values for Amy/kg DM have been calculated assuming a dietary energy density of 4,000 kcal ME/kg. (The term = signifies equivalence.) If the energy density of the diet is not 4,000 kcal ME/kg, then to calculate the Amy/kg DM for each nutrient, multiply the value for the nutrient in the column labeled Amy/kg DM by the energy density of the pet food (in kcal ME/kg) and divide by 4,000.

*To calculate the amount to feed to each animal, multiply the value for Amy/1,000 kcal ME for each nutrient by the energy requirement in kcal (calculated from Tables 15-6 and 15-7) and divide by 1,000.

*The values for Amy/BW (kg) apply only to a 22-kg bitch in peak lactation with 8 puppies and consuming 5,000 kcal/day. To calculate the amount for bitches of different body weights or litter sizes, calculate the energy requirement from Table 15-7 and multiply this value by the nutrient Amy/1,000 kcal and divide by 1,000. To calculate the amount of a nutrient for gestating bitches, calculate the energy requirement from Table 15-6, and multiply this value by the nutrient Amy/1,000 kcal and divide by 1,000.

*0.01 g arginine should be added for every g of crude protein above 200.

*The quantity of tyrosine required to maximize black hair color may be about 1.5-2.0 times this quantity.

*The requirement for α-tocopherol varies depending upon the tocopherol content of the diet. The ratio of linoleic acid to α-tocopherol acid should be between 2.6 and 16. Note that 0.8 μg/kg DM value shown is the minimum RA of α-tocopherol acid at 13 g linoleic acid per kg DM, resulting in a ratio of linoleic acid to α-tocopherol acid of approximately 16.

*50-60% of the total amount should be eicosapentaenoic acid and 40-50% should be docosahexaenoic acid.

*Sodium content of iron and copper should not be used because of low bioavailability.

*Vitamin A requirements expressed as RE (retinol equivalents). One RE is equal to 1 μg of all-trans retinol, and one IU of vitamin A is equal to 0.3 RE. Safe upper limits values expressed as μg retinol.

*1 μg cholecalciferol = 40 IU vitamin D3.

*Higher concentrations of vitamin E are recommended for high PUFA diets. One international unit of vitamin E = 1 mg all-trans-α-tocopherol acetate (see Chapter 8).

*Dog's have a metabolic requirement, but a dietary requirement has not been demonstrated when natural diets are fed. Adequate vitamin K is probably synthesized by intestinal microflora. The vitamin K allowance is expressed in terms of the commercially used precursor menadione that requires activation to the active vitamin K.

*For normal diets not containing raw egg white, adequate biotin is probably provided by microbial synthesis in the intestine. Diets containing antibiotics may need supplementation.
### Table 15-10 Nutrient Requirements for Growth of Kittens after Weaning

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kg BW</td>
<td>g/kg DM</td>
<td>g/kg DIG</td>
</tr>
<tr>
<td>ME (kcal)</td>
<td>7.7-9.4</td>
<td>25.5-34.5</td>
<td>56.5-114</td>
</tr>
<tr>
<td>BW = Body weight at time of evaluation (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME (kcal = 100 x BW x 7.7 x 0.011 x 0.66)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW = expected mature body weight (kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ME (kcal = 100 x BW x 7.7 x 0.011 x 0.66)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assumptions:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Body weight of kittens after weaning is 2.5-3.5 kg.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Daily growth is 20-25 g.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Daily weight gain is 20-25 g.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Example:**

For ME (kcal) calculation: ME (kcal) = 100 x BW x 7.7 x 0.011 x 0.66

For BW calculation: BW = expected mature body weight (kg)

For weight gain calculation: Weight gain = 20-25 g
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Amount (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnesium</td>
<td>160</td>
</tr>
<tr>
<td>Sodium</td>
<td>1,400</td>
</tr>
<tr>
<td>Potassium</td>
<td>268</td>
</tr>
<tr>
<td>Chloride</td>
<td>760</td>
</tr>
<tr>
<td>Copper</td>
<td>0.45</td>
</tr>
<tr>
<td>Zinc</td>
<td>50.2</td>
</tr>
<tr>
<td>Manganese</td>
<td>120</td>
</tr>
<tr>
<td>Selenium</td>
<td>1.80</td>
</tr>
<tr>
<td>Iodine</td>
<td>1.00</td>
</tr>
<tr>
<td>Vitamin A (µg retinol)</td>
<td>2.78</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>8.8</td>
</tr>
<tr>
<td>Vitamin E (α-tocopherol)</td>
<td>0.70</td>
</tr>
<tr>
<td>Vitamin K (Menadione)</td>
<td>3.8</td>
</tr>
<tr>
<td>Thiamin</td>
<td>4.4</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.6</td>
</tr>
<tr>
<td>Pyridoxine</td>
<td>0.2</td>
</tr>
<tr>
<td>Nicotinamide</td>
<td>0.2</td>
</tr>
<tr>
<td>Pantothenic Acid</td>
<td>1.0</td>
</tr>
<tr>
<td>Folic Acid</td>
<td>5.0</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.1</td>
</tr>
<tr>
<td>Choline</td>
<td>2.04</td>
</tr>
</tbody>
</table>

*The values for AM/kg DM have been calculated assuming a dietary energy density of 4,000 kcal ME/kg. (The term “K” signifies equivalence.) If the energy density of the diet is not 4,000 kcal ME/kg, then to calculate the AM/kg DM for each nutrient, multiply the value for the nutrient in the column labeled AM/kg DM by the energy density of the pet food (in kcal ME/kg) and divide by 4,000.

*To calculate the amount to feed of each nutrient, multiply the value for AM/kg (AM for each nutrient by the energy requirement in kcal for the pet food (calculated from Table 15-9) and divide by 1,000.

*The values for AM/BW apply only to 1,000 g kits with an expected mature body weight of 4 kg. To calculate the amount for kits of different actual or expected mature body weights, calculate the energy requirement from Table 15-9 and multiply this by the nutrient AM/kg and divide by 1,000.

*0.02 g arginine should be added for every g of crude protein above 100 g and 225 g for the MR and EA, respectively.

*To minimize black tar color, an equal quantity of vitamin A is required.

*The recommended allowance of thiamine for highly digestible purified diets is 0.4 µg/kg diet, whereas the allowances for dry expanded and canned diets are 1.0 g and 1.7 g/kg DM respectively.

*It is advisable that cholineplasmatic acid not exceed 0.5% of the total plasmatic acid + desoxycholic acid amount.

*Some forms of iron and copper should not be used because of low bioavailability.

*One IU of vitamin A is equivalent 0.3 µg of all-trans retinol or 1 µg retinol = 3,333 IU of vitamin A. Safe upper limit values expressed as µg retinol.

*1 µg cholecalciferol = 40 IU vitamin D3.

*Higher concentrations of vitamin E are recommended for high PPUA diets. One international unit of vitamin E = 1 mg all-tocopherol (assay value = Chapter 8).

*Cats have a metabolic requirement, but a dietary requirement has not been demonstrated when natural diets (except fish-based diets) are fed. Under most conditions, adequate vitamin K is probably synthesized by intestinal microbes. The vitamin K allowance is expressed in terms of the commercially available precursors manganeso that requires alkylation to the active vitamin K.

*For normal diets not containing raw egg white, adequate biotin is probably provided by microbial synthesis in the intestine. Diets containing antibiotics may need supplementation.
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimum Requirement</th>
<th>Adequate Intake</th>
<th>Recommended Allowance</th>
<th>Safe Upper Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein (g)</td>
<td>200</td>
<td>250</td>
<td>400</td>
<td>550</td>
</tr>
<tr>
<td>Amino Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arginine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Histidine</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Leucine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Lysine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Phytate (g)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Threonine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total Fat (g)</td>
<td>100</td>
<td>120</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>Fatty Acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linoleic Acid (g)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>α-Linolenic Acid (g)</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Arachidonic Acid (g)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Docosahexaenoic Acid (g)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>156</td>
<td>156</td>
<td>156</td>
<td>156</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>156</td>
<td>156</td>
<td>156</td>
<td>156</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Chloride (mg)</td>
<td>52</td>
<td>52</td>
<td>52</td>
<td>52</td>
</tr>
</tbody>
</table>

Notes:
1. Values are per kg of feed.
2. Values are per 1,000 kcal of feed.
3. Values are per 4,000 kcal of feed.
4. Values are per BW of 3 kg.
5. Values are per BW of 5 kg.
The values for Amn/Ag: DM have been calculated assuming a dietary energy density of 4,000 kcal ME/kg. If the energy density of the diet is not 4,000 kcal ME/kg, then in the revision below, the Amn/Ag: DM for each nutrient, multiply the value for Amn/Ag: DM by the energy density of the diet (kJ/kg ME/kg) and divide by 4,000.

To calculate the amount of food for each nutrient, multiply the value for Amn/Ag: DM by the energy requirement for low-energy diets (kJ/kg ME/kg) and divide by 1,000. For cats with an unusually low energy intake (below the suggested requirement), the nutrient concentrations (Amn/Ag: DM) may not be adequate. These animals should be fed the nutrient amounts shown in the column Amn/Ag: BW.

The values in Amn/Ag: BW have been calculated for a cat with an energy intake of 100 kcal kg today. To calculate the amounts for adults that are not lean, calculate the energy requirements from Table 15.1 and multiply this value by the nutrient Amn/Ag: BW cal and divide by 1,000.

IU gamma-tocopherol should be added for every 10 mg of cholecalciferol from 250 IU for the RA of vitamin E.

Methionine is presented to be one-half the sum of the requirement for methionine + cysteine combined.

Whole-body black hair color, an equal quantity or greater of tyrosine to that of phenylalanine is required.

The recommended allowance of vitamin E for highly digestible, purified diets is 0.4 g/kg diet, whereas the allowances for dry expanded and canned diets are 1.0 and 1.7 g/kg diet, respectively.

Includes cholic acid, chenodeoxycholic acid, and other bile acids. It is considered that cholic acid is included but not exceeded 20% of the total cholic acid + chenodeoxycholic acid.

Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.

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Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.

Some studies of iron and copper should not be used because of low bioavailability.
Table 15-14  Nutrient Requirements of Queens in Late Gestation and Peak Lactation

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Minimal Requirement</th>
<th>Adequate Intake</th>
<th>Recommended</th>
<th>Mammal</th>
<th>Adult Male (kg)</th>
<th>Adult Female (kg)</th>
<th>Adult Male (g)</th>
<th>Adult Female (g)</th>
<th>Adult Male (mg)</th>
<th>Adult Female (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude Protein</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Aspartic Acid</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Glutamic Acid</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Leucine &amp; Isoleucine</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Methionine &amp; Cystine (g)</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Valine, Leucine &amp; Isoleucine (g)</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Phosphorus (mg)</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table continues...
<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Requirement (g/day)</th>
<th>RDA (g/day)</th>
<th>Daily Intake (g/day)</th>
<th>Estimated Excretion (g/day)</th>
<th>Daily Requirement (g/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tyrosine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.60</td>
<td>0.15</td>
<td>0.32</td>
<td>0.19</td>
<td>0.60</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.55</td>
<td>0.14</td>
<td>0.24</td>
<td>0.15</td>
<td>0.55</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.55</td>
<td>0.14</td>
<td>0.24</td>
<td>0.15</td>
<td>0.55</td>
</tr>
<tr>
<td>Methionine</td>
<td>0.32</td>
<td>0.08</td>
<td>0.12</td>
<td>0.08</td>
<td>0.32</td>
</tr>
<tr>
<td>Cysteine</td>
<td>0.24</td>
<td>0.06</td>
<td>0.08</td>
<td>0.05</td>
<td>0.24</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.55</td>
<td>0.14</td>
<td>0.24</td>
<td>0.15</td>
<td>0.55</td>
</tr>
<tr>
<td>Arginine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Valine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.32</td>
<td>0.08</td>
<td>0.12</td>
<td>0.08</td>
<td>0.32</td>
</tr>
<tr>
<td>Alanine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Proline</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Glutamine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
<tr>
<td>Asparagine</td>
<td>0.42</td>
<td>0.105</td>
<td>0.22</td>
<td>0.13</td>
<td>0.42</td>
</tr>
</tbody>
</table>

*With the exception of amino acids, few data can be found for the dietary concentrations for the minimal requirement for gestation for the queen. For other nutrients, the values for lactation relative to kg DM and 1,000 kcal ME may be taken as satisfactory for gestation and lactation in the queen.

*The values for Amt/kg DM have been calculated assuming a dietary energy density of 4,400 kcal/kg ME/kg. The energy density of the diet is not 4,000 kcal ME/kg, then calculate the Amt/kg DM for each nutrient, multiply the value for the nutrient by the column labeled Amt/kg DM by the energy density of the diet, and divide the result by 4,000.

*To calculate the amount of feed of each nutrient, multiply the values for Amt/kg ME for each nutrient by the energy requirement in kg ME (calculated from Table 15-13 for a queen during gestation) divided by 4,000.

*The values for Amt/kg BW are only applicable to queen weighing 4 kg in peak lactation with 3-4 kittens consuming 54 kcal ME/kg. If the queen does not meet these criteria, calculate the ME requirement from Table 15-13, multiply this value by 0.001 kcal ME/kg and divide by 4,000. To calculate the nutrient requirements for lactation, compute the energy requirements from 40 x kg BW and multiply by 0.001 kcal ME/kg and divide by 4,000.

*0.2 g arginine added for every 0.1 g of crude protein above 170 g and 3.1 g for the ME and RA, respectively.

*0.2 g methionine or cysteine for every 0.1 g of crude protein above 170 g.

*1 mg choline chloride = 40 IU vitamin B1.

*Higher concentrations of vitamin A are recommended for high PCV diets; 0.5 mg instead of 0.4 mg as retinol acetate (see Chapter 1).

*5 mg ascorbic acid = 1 mg vitamin C.

*Can have a metallothionein requirement, but a dietary requirement has not been demonstrated when diets containing 0.012 mg/kg diet are fed. Under most conditions, adequate vitamin K is probably synthesized by intestinal microbes. The vitamin K requirement in terms of the commercially pure product is 1 mg/kg diet.

*For normal diet not containing raw egg white, adequate hosts is probably provided by microbial synthesis in the intestines. Dried containing antibodies may need supplementation.
Attachment F -- References and Research Information


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