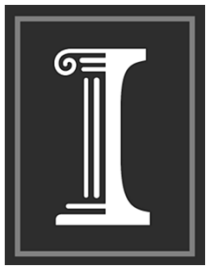
Amino acid nutrition of dogs and cats: Requirements vs. actual feeding practices

Alison N. Beloshapka, Ph.D., Kelly S. Swanson, Ph.D., and George C. Fahey, Jr., Ph.D.

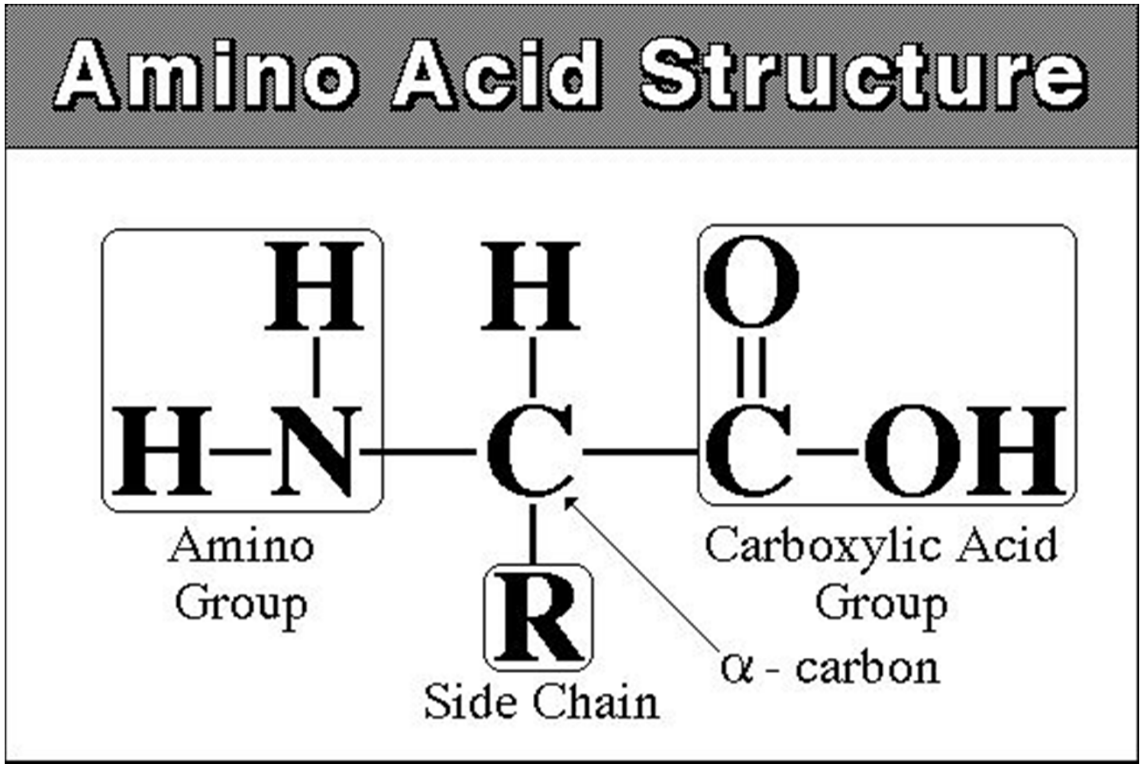
University of Illinois at Urbana-Champaign





Amino Acids (AA)

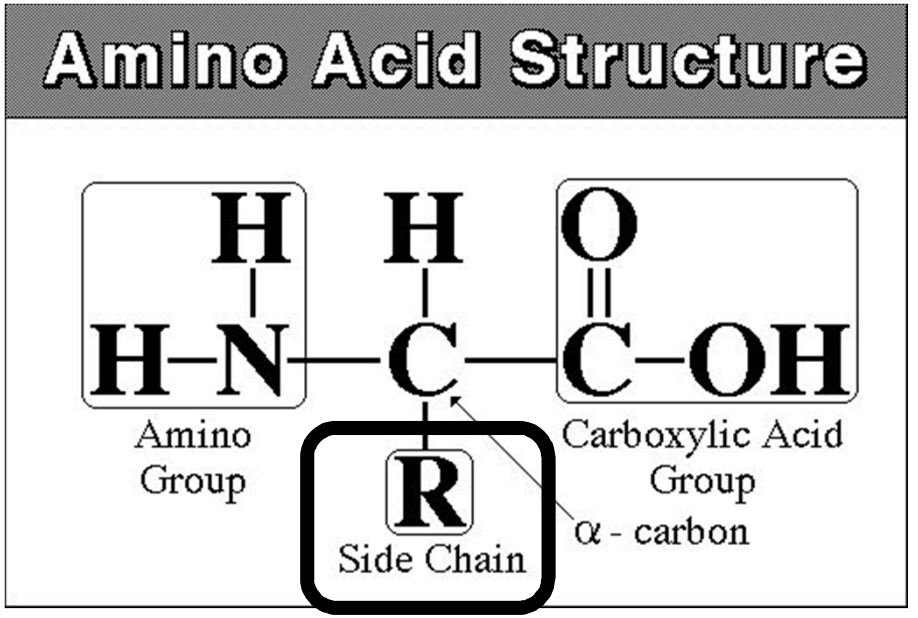
- Amino acids (AA) are the basic units that compose proteins



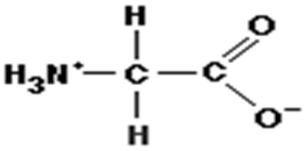
Amino Acids

- Side chain differentiates AA

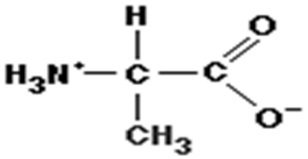
- 4 primary groups of AA
  - Non-polar
  - Polar—neutral
  - Polar—acidic
  - Polar—basic



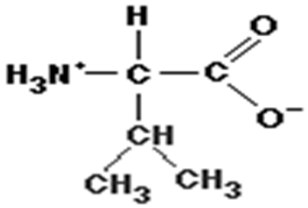
Nonpolar Amino Acids (AA)



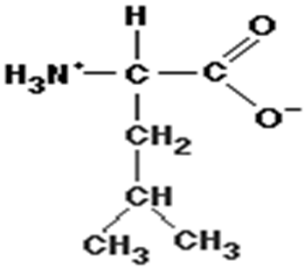
Glycine (Gly)



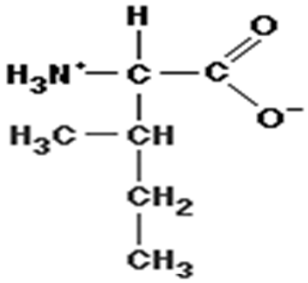
Alanine (Ala)



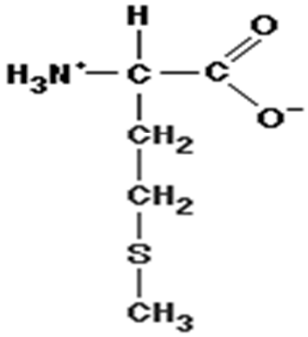
Valine (Val)



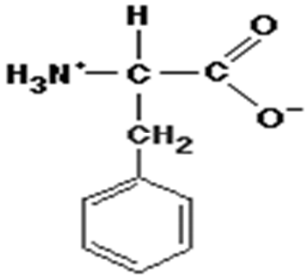
Leucine (Leu)



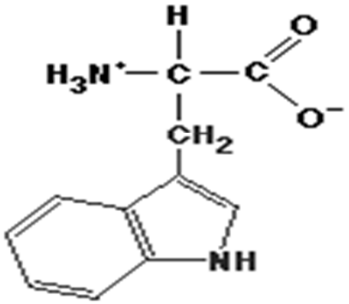
Isoleucine (Ile)



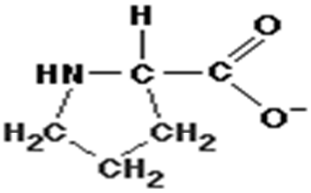
Methionine (Met)



Phenylalanine (Phe)

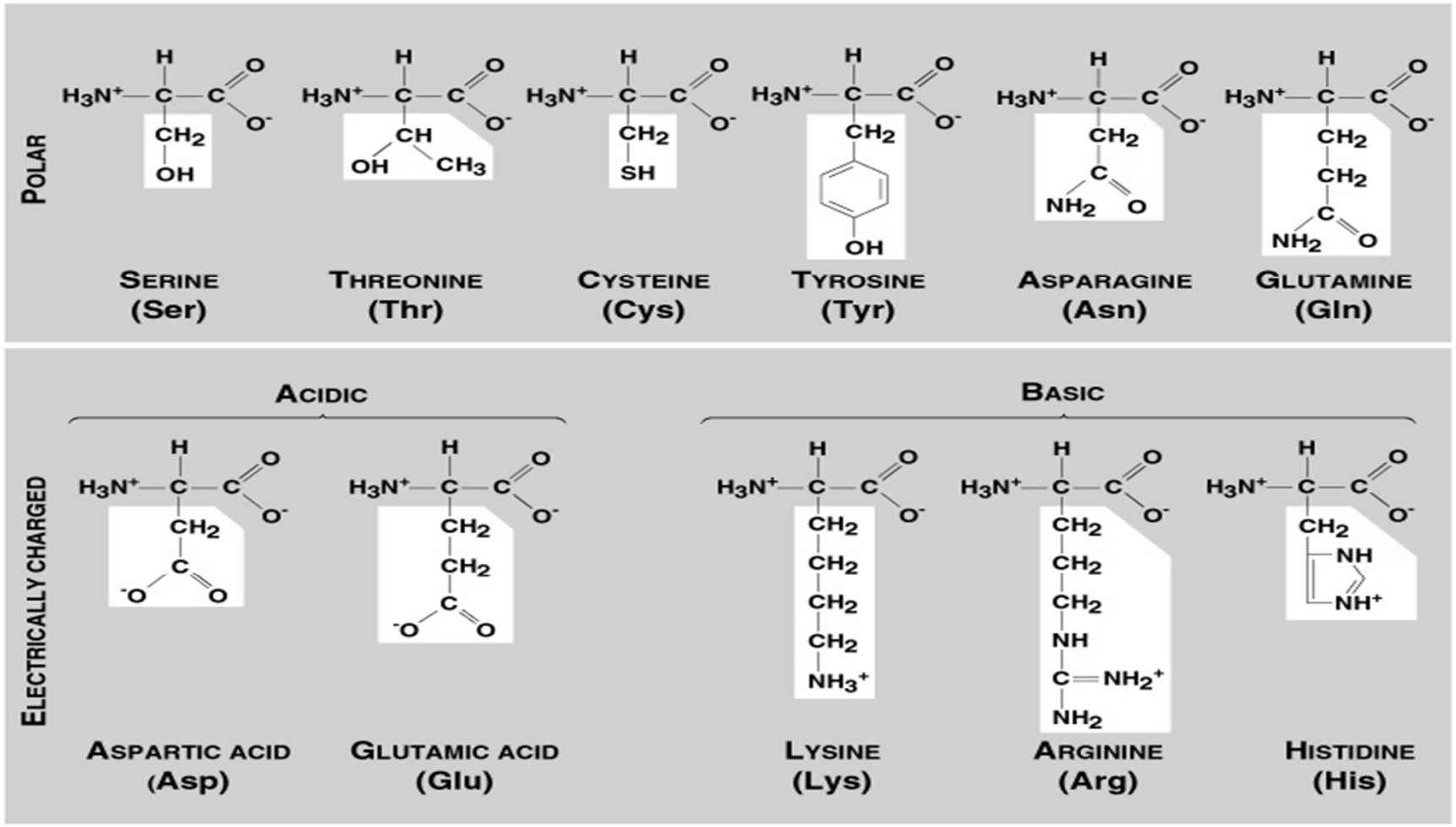


Tryptophan (Trp)



Proline (Pro)

Polar Amino Acids (AA)



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Essential vs. Non-essential AA

- 22 AA required for proper function
  - 10 essential AA in diet of dogs and cats

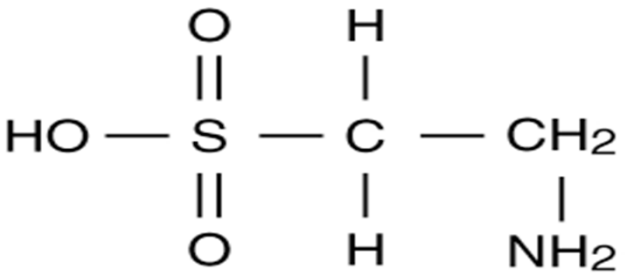
*Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Tryptophan
Leucine	Threonine
Lysine	Valine

  - *Arginine is essential for adult dogs and cats (is NOT essential for many adult animals)
  - 12 non-essential
    - Can be synthesized to meet body's needs if sufficient N in diet (liver)

Essential vs. Non-essential AA

- Essential AA
  - Not synthesized at a rate sufficient for normal maintenance and growth
- Thus, a dietary requirement exists:
  - Essential AA
  - Nitrogen
    - Synthesis of non-essential AA
    - Other essential N-containing compounds
- 1 beta-sulfonic acid present in body
  - Taurine
    - Essential for the cat
    - Appears to be for some breeds of dog, too

Taurine



Essential vs. Non-essential AA

- **Recommendations/requirements for an adult dog:**

Nutrient	AAFCO Nutrient Profiles (% of diet)	NRC	
		Min. Req. (% of diet)	Recommended Allowance (% of diet)
Crude Protein	18	8	10
Amino Acids (AA)	--	--	--
Arginine	0.51	0.35	0.35
Histidine	0.18	0.19	0.19
Isoleucine	0.37	0.38	0.38
Leucine	0.59	0.68	0.68
Lysine	0.63	0.35	0.35
Methionine	--	0.33	0.33
Methionine & Cystine	0.43	0.65	0.65
Phenylalanine	--	0.45	0.45
Phenylalanine & Tyrosine	0.73	0.74	0.74
Threonine	0.48	0.43	0.43
Tryptophan	0.16	0.14	0.14
Valine	0.39	0.49	0.49

Essential vs. Non-essential AA

- **Recommendations/requirements for an adult cat:**

Nutrient	AAFCO Nutrient Profiles (% of diet)	NRC Min. Req. (% of diet)	NRC Recommended Allowance (% of diet)
Crude Protein	26	16	20
Amino Acids (AA)	--	--	--
Arginine	1.04	0.77	0.77
Histidine	0.31	0.26	0.26
Isoleucine	0.52	0.43	0.43
Leucine	1.25	1.02	1.02
Lysine	0.83	0.34	0.34
Methionine	0.62	0.17	0.17
Methionine & Cystine	1.1	0.34	0.34
Phenylalanine	0.42	0.40	0.40
Phenylalanine & Tyrosine	0.88	1.53	1.53
Threonine	0.73	0.52	0.52
Tryptophan	0.16	0.13	0.13
Valine	0.62	0.51	0.51
Taurine	0.1-0.2	0.04	0.04

Protein Requirements

- AAFCO Nutrient Profiles
  - Not requirements, but recommendations*

Species	Growth & Repro.	Adult Maint.
Dog	22%	18%
Cat	30%	26%
Human		~10%
Rat	17.9% (AIN-93G)	12.6% (AIN-93M)

*Assumes 3.5 kcal ME/g DM (dog) and 4 kcal ME/g DM (cat)

Protein Requirements

- **NRC Recommended Allowance***

Species	4-14 wk	>14 wk	Adult Maint.
Puppies	22.5%	17.5%	10.0%
Kittens	22.5%		20.0%
Human (0.8 g/kg BW)			~10%
Rat	NA	17.9% (AIN-93G)	12.6% (AIN-93M)

*Assumes 4 kcal ME/g DM for dogs and cats

Factors Affecting Protein Requirements

- Protein digestibility
- Protein quality
- Caloric density of diet
- Physiological state of animal

Factors Affecting Protein Requirements

- **Protein digestibility**
- Protein quality
- Caloric density of diet
- Physiological state of animal

Protein Digestion

- Amount absorbed by animal
  - Digestibility vs. availability
- Digestibility = (intake – output)/intake*100
- ↑ digestibility → ↓ needed as a % of the diet

Protein Digestibility

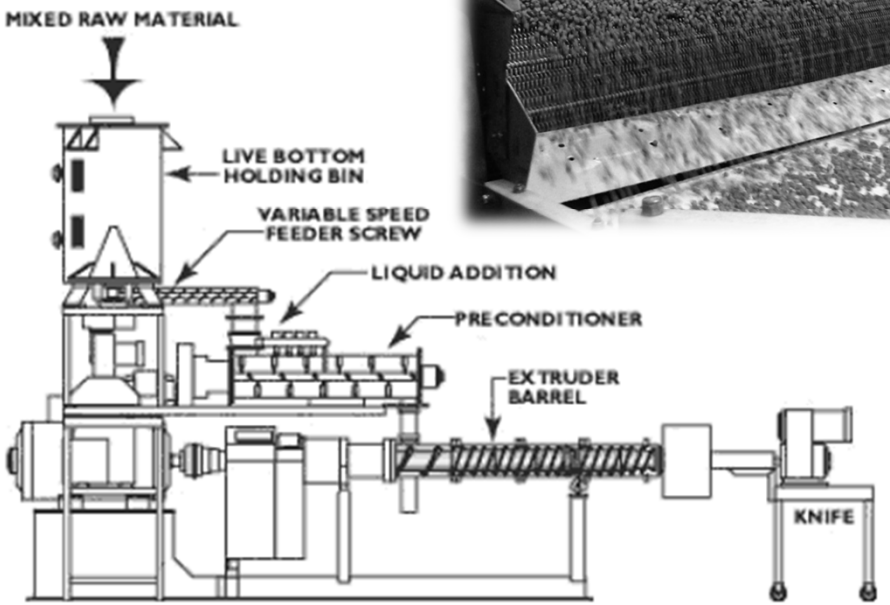
- Factors of importance
  - Physical characteristics
    - Solubility
    - Chemical bonding
    - Structure
  - Anti-nutritional components
    - Trypsin inhibitors (soybeans)
  - Dietary fiber intake



Protein Digestibility

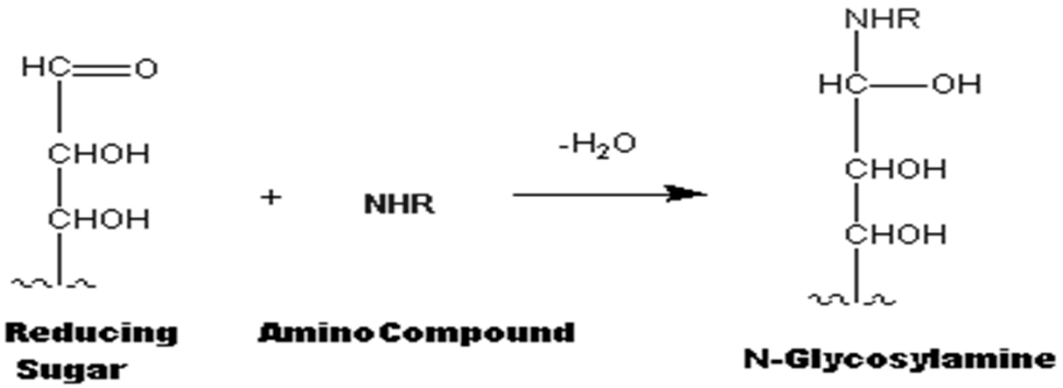
- Factors of importance
  - Processing conditions
    - Boiling
    - Drying
    - Pelleting
    - Extrusion
    - Autoclaving
    - Toasting





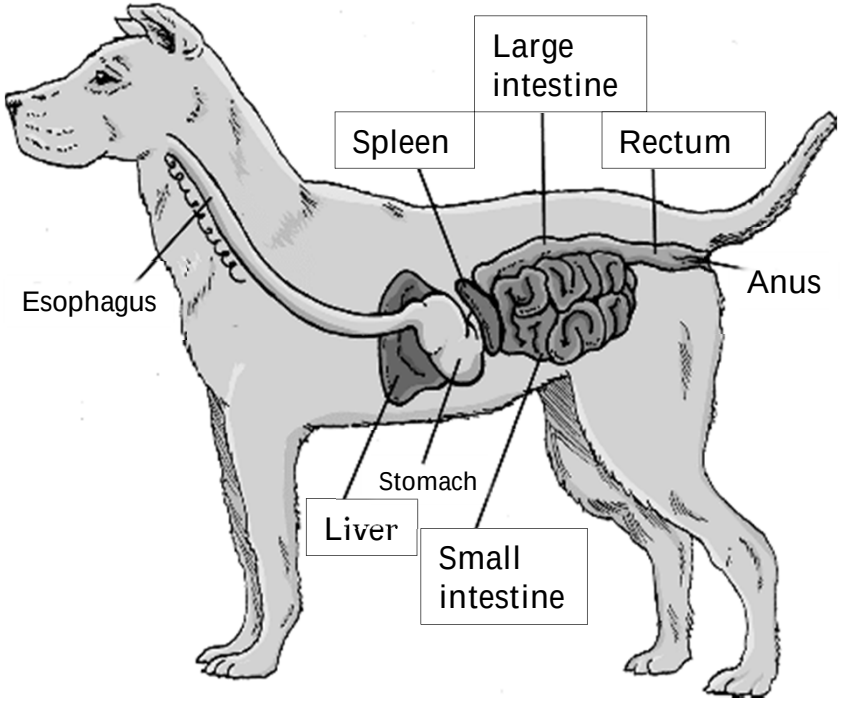
Protein Digestibility

- Factors of importance
  - Processing conditions
    - Maillard browning reaction
      - Reducing sugar + available amino group
      - Affects lysine availability



Digestibility Measurements

- Fecal sampling (total tract)
  - Inaccurate measure of protein digestibility
    - Endogenous secretions
      - Digestive enzymes
      - Mucins
      - Sloughed epithelial cells
    - Bacterial alterations



Digestibility Measurements

- **Bacterial fermentation**
  - **AA deaminated by microbes**
    - **Energy**
    - **Amino acids of microbial origin**
  - **Proteins entering colon ≠ proteins in feces**
  - **<u>Remember:</u> colon does not absorb AA**
  - **<u>Remember:</u> NH_3 recycled**

Digestibility Measurements

- Ileal digestibility most accurate
  - Use of ileal-cannulated dogs and pigs



Digestibility Measurements

Item	CP digestibility, %	
	Ileum	Total tract
SBM (4 experiments)	78.6 (77.4 – 79.2)	84.7 (82.7 – 84.6)
Animal proteins (8 experiments)	75.2 (65.1 – 77.2)	86.2 (77.2 – 89.8)

Factors Affecting Protein Requirements

- Protein digestibility
- **Protein quality**
- Caloric density of diet
- Physiological state of animal

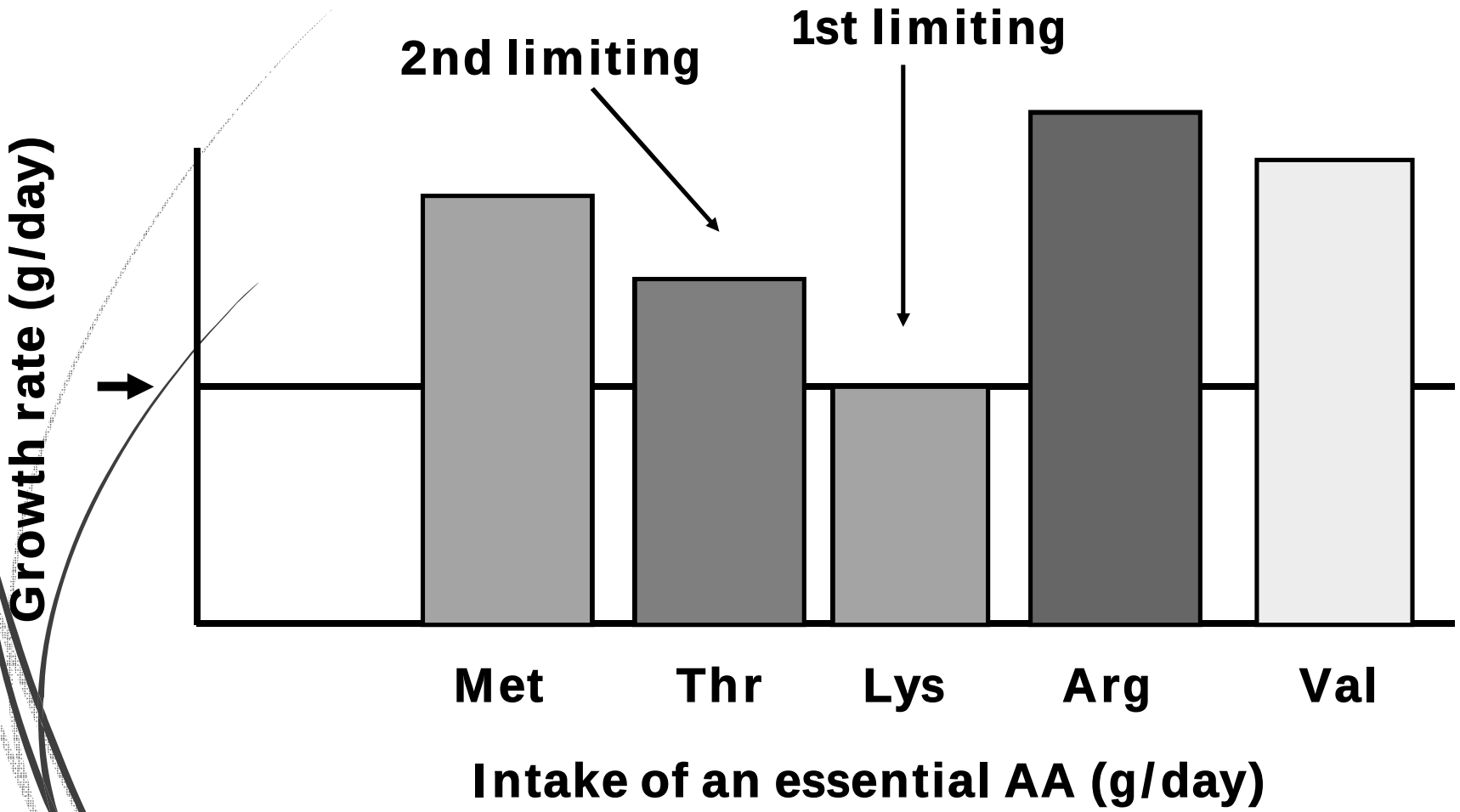
Protein Quality

- Ability of a protein source to meet the N and AA requirements of an animal
- Consumer views about “high quality” protein
  - Low fat content, avoid preservatives, human grade, etc.
- Affected by the AA profile and/or processing

Protein Quality

- AA composition
  - 10 essential AA for most species
- Ideal AA profile
  - Not only specific amounts, but specific proportions to one another
    - Based on pattern of AA required for protein synthesis (measured as growth)
    - Usually expressed relative to lysine
    - Limiting AA principle

Principle of Limiting AA



Protein Quality

- Want AA profile that best matches needs of animal
- Better match → ↓ dietary protein requirement
- Protein quality measured by
  - Protein efficiency ratio (PER)
  - Precision- fed cecectomized rooster assay

Protein Efficiency Ratio (PER)

$$\text{PER} = \frac{\text{Gain in body weight (g)}}{\text{Protein consumed (g)}}$$

- **Weanling rats (21 d old) or young chickens are commonly used for this assay**

Protein Efficiency Ratio (PER)

Source	PER
Egg	3.8
Casein	2.8
Soy	2.4
Wheat gluten	0.4
Gelatin	0.0

*Rats fed a single protein source for 10 days



Precision-fed Cecectomized Rooster Assay

- Removal of ceca
- Crop intubation of the test ingredient
- Collection of excreta
- Correction for endogenous materials using fasted roosters
- Response criteria measured: true metabolizable energy and true amino acid digestibility






12
13
14
15
16

Comparison of cecectomized rooster vs. ileal cannulated dog data

Item	Lysine digestibility, %		
	Rooster (meals)	Rooster (dog foods)	Dog
MBM, low-temperature	86	93	83
MBM, high-ash	76	86	84
MBM, low-ash	71	71	70
PBP, high-ash	74	76	64
PBP, low-ash	70	71	66
Lamb meal, low-ash	63	60	62

Item	Methionine digestibility, %		
	Rooster (meals)	Rooster (dog foods)	Dog
MBM, low-temperature	84	92	93
MBM, high-ash	80	93	93
MBM, low-ash	73	85	87
PBP, high-ash	80	88	85
PBP, low-ash	76	85	83
Lamb meal, low-ash	72	83	84

Ingredient	TMEn (kcal/g DM)
Maltodextrin	4.06
Fructose	3.99
Sorbitol	3.84
Pullulan	3.33
Soluble Fiber Dextrin	2.19
Resistant Starch	1.89
Polydextrose	1.74

Factors Affecting Protein Requirements

- Protein digestibility
- Protein quality
- **Caloric density of diet**
- Physiological state of animal

Caloric Density

- ↑ caloric density → ↑ protein (per gram diet) required in diet
  - WHY??
- Food intake affected
  - Most accurate to calculate requirements based on unit of energy
  - <u>Reminder:</u>
    - AAFCO: assumes 3.5 kcal ME/g for dogs
      - Diets > 4.0 kcal ME/g need adjustments
    - NRC: assumes 4.0 kcal ME/g (dog & cat)
      - Diets > 4.5 kcal ME/g need adjustments

Factors Affecting Protein Requirements

- Protein digestibility
- Protein quality
- Caloric density of diet
- **Physiological state of animal**

Physiological State

- **Usually:**

  Maintenance < gestation < growth < lactation









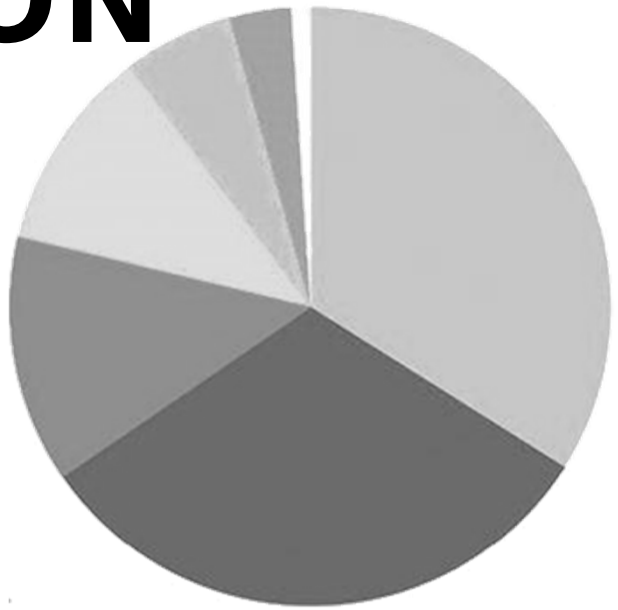
Practical Issues Related to Protein/Amino Acid Nutrition

Why do we feed such high protein concentrations in the diets of dogs and cats?

Dog ~ 30%

Cat ~ 35%

PET FOOD MARKET SEGMENTATION



For the U.S. and Europe, the Market is Segmented Into:

- Generic brands
- Popular brands
- Premium brands
- Super-premium brands
- Veterinary brands

For Brazil, the Market is Segmented Into:

- Economic (basic) brands
- Standard brands
- Premium brands
- Super-premium brands
- Veterinary brand emerging

- **Premium and super-premium diets are those that contain the highest concentration of protein.**
  - **Protein quality usually is highest in these diets as well.**

Feeding Protein in Excess of the Requirement is:

- **NOT A NUTRITION ISSUE!**

- **Rather, an animal management issue handled by nutritional intervention.**









If Dogs Are To Live in the House With Humans, They Must Follow These Rules:

- Provide companionship
- Demonstrate loyalty
- Be loving and affectionate
- Etc., etc.
- AND DON'T POOP ON THE FLOOR!!!

So How Do We Prevent This?

- Feed a diet with a dry matter digestibility 80-85%.

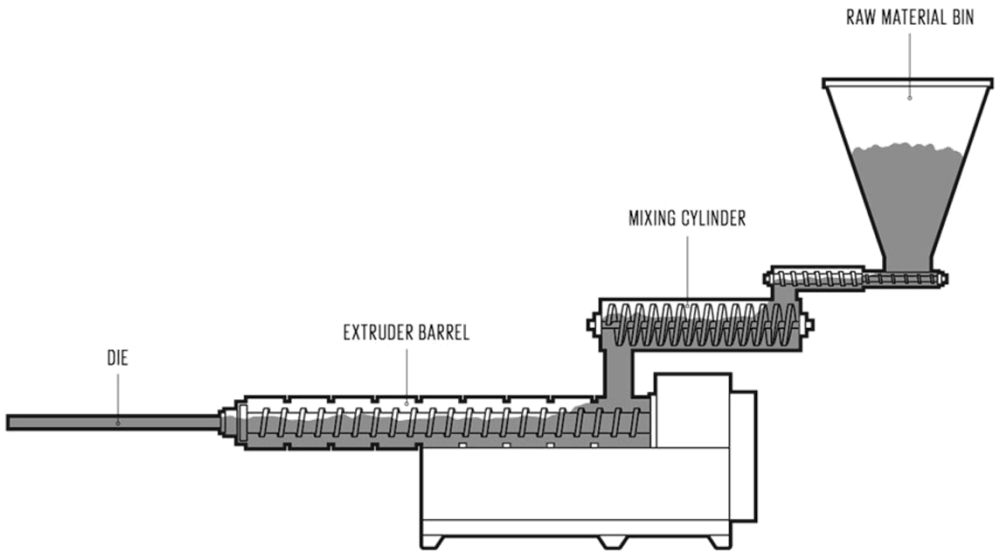
- This high digestibility will occur only if we feed relatively large quantities of good quality proteins and fats, and carefully manage the types of carbohydrates, both non-structural (e.g., starch) and structural (e.g., fiber), present.





Other Reasons for Feeding Excess Dietary Protein?

- Processing losses
  - AA losses can be compensated for by increasing level of AA (e.g., lysine)
    - ↑ cost



Other Reasons for Feeding Excess Dietary Protein?

- Ingredient variability
  - Wide variety of animal-based protein sources available to formulators
  - Major issues include:
    - Animal species variability
    - “Parts” of animal used
    - Processing method

Murray et al., 1997; Dust et al., 2005; Husak et al., 2008; Faber et al., 2010; Kerr et al., 2010

What Happens to Excess Amino Acids?

- Pass into the large bowel where they are fermented
- End-products of amino acid fermentation:
  - Amines → some are cell growth regulators; others are toxic
  - Ammonia → toxic in high concentrations
  - Phenols & indoles → toxic, contribute to odor of feces
  - Branched-chain fatty acids → contribute to odor of feces
  - Bacterial cells → contribute to fecal mass
  - Gases → i.e., H_2S – toxic, odor-producing

Zuccato et al. (1993); Silvester et al. (1997); Babidge et al. (1998); Ichikawa & Sakata (1998); Hughes et al. (2000); Magee et al. (2000); Jorgensen and Mortensen (2001)

What Protein Sources May Be Used to Meet Amino Acid Requirements?

Proteinaceous Ingredients

- Contain at least 20% crude protein
- Animal sources
  - Animal sources may or may not be suitable for human consumption
  - Most are by-products of
    - Meat packing
    - Poultry processing
    - Fish canning
  - Plant sources



Animal Proteins

- May be highly variable in content
  - Protein
  - Fat
  - Minerals



- Quality also variable
  - Chemical composition
  - Processing conditions
- Raw or rendered products used



Rendering

- Processing of raw material
- Fractionation
  - Water
  - Fat
  - Solids
    - Protein-rich fraction
- Heating (138ºC) and drying
  - ↓ bacterial and viral contamination



Animal Proteins

- Must use AAFCO feed ingredient definitions
  - Meat meals
  - Meat and bone meals
  - Byproduct meals



Meat Meals



- Common species
  - Beef
  - Lamb
  - Poultry
  - Fish
- Significant portion produced is used by petfood industry
  - ~25% of poultry byproducts

Meat Meals

- Rendered products
- May include:
  - Skeletal muscle
  - Tongue
  - Diaphragm
  - Heart
  - Esophagus
  - Overlaying fat, attached nerves, and blood vessels
- May NOT contain added:
  - Blood
  - Hair
  - Horn
  - Hoof
  - Hide trimmings
  - Manure
  - GI contents

Meat and Bone Meal

- As defined, must be from mammals
  - Most byproducts of beef slaughter
- High in minerals
- Low in methionine and cystine





Poultry ByProduct Meal

- Common animal protein used in petfoods
- Highly variable
  - Fat content
  - Ash content
    - Ca
    - P



Fish Meal

- 2 main types
  - Fishery waste from human industry
    - Salmon; tuna
  - Fish harvested specifically for fish meal production
    - Herring; menhaden





- Odor issues
- Fat oxidation issues
- Good mineral source

Dried Egg Products

- Eggs inedible by humans
  - Broken shells
  - Blood spots
- Centrifugation, pasteurization, spray dried, and packaged
- High protein quality
- Often added in small amounts
  - “Tag appeal”





Unique Animal Proteins

- Duck
- Venison
- Turkey
- Lamb
- Bison
- Individual organs
  - Liver
  - Kidney
  - Lung

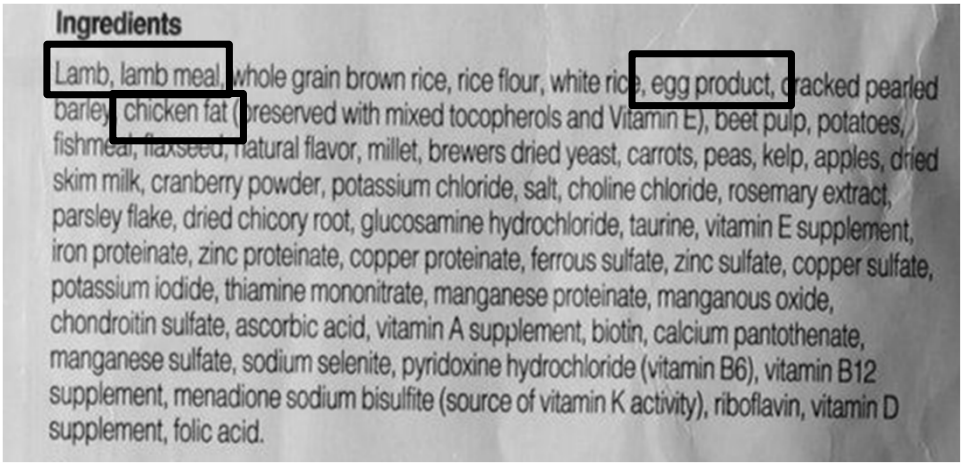






Animal Protein Sources

- Advantages
  - Good quality AA profile
  - Source of fat
  - Source of minerals (Ca; P)
  - Label (tag) appeal



Ingredients

Lamb, lamb meal, whole grain brown rice, rice flour, white rice, egg product, cracked pearled barley, chicken fat (preserved with mixed tocopherols and Vitamin E), beet pulp, potatoes, fishmeal, flaxseed, natural flavor, millet, brewers dried yeast, carrots, peas, kelp, apples, dried skim milk, cranberry powder, potassium chloride, salt, choline chloride, rosemary extract, parsley flake, dried chicory root, glucosamine hydrochloride, taurine, vitamin E supplement, iron proteinate, zinc proteinate, copper proteinate, ferrous sulfate, zinc sulfate, copper sulfate, potassium iodide, thiamine mononitrate, manganese proteinate, manganous oxide, chondroitin sulfate, ascorbic acid, vitamin A supplement, biotin, calcium pantothenate, manganese sulfate, sodium selenite, pyridoxine hydrochloride (vitamin B6), vitamin B12 supplement, menadione sodium bisulfite (source of vitamin K activity), riboflavin, vitamin D supplement, folic acid.

Animal Protein Sources

- Disadvantages
  - Highly variable
    - Composition
      - Trimmings
      - Viscera
      - Fat
      - Bone
      - Heads, feathers, etc.



Animal Protein Sources

- Disadvantages
  - Highly variable
    - Quality
      - Dependent on composition
    - Digestibility
      - Processing conditions



Animal Protein Sources

- Highly variable
  - Example: Meat and bone samples

Item, % DM	Range	Average
Crude protein	46.5 – 60.4	53.2
Collagen	20.7 – 38.7	25.2
Ash	22.1 – 44.1	30.9
Lysine	2.2 – 3.1	2.8

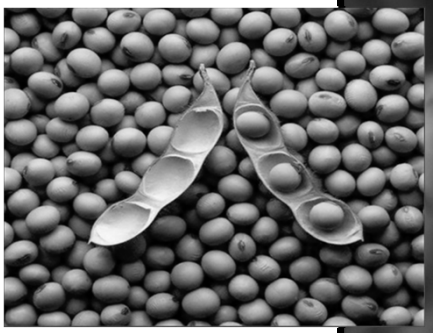
Animal Protein Sources

- Factors affecting quality
  - Collagen and connective tissue
    - Decrease quality
    - Decrease EAA:NEAA ratio
  - Ash content



Plant Proteins

- Soybeans and soybean meal common
  - Heat-treatment required
  - Anti-nutritional factors
    - Protease (trypsin) inhibitors
    - Lectins – bind carbohydrate – containing molecules
    - Phytate – ↓ mineral digestibility





Plant Proteins

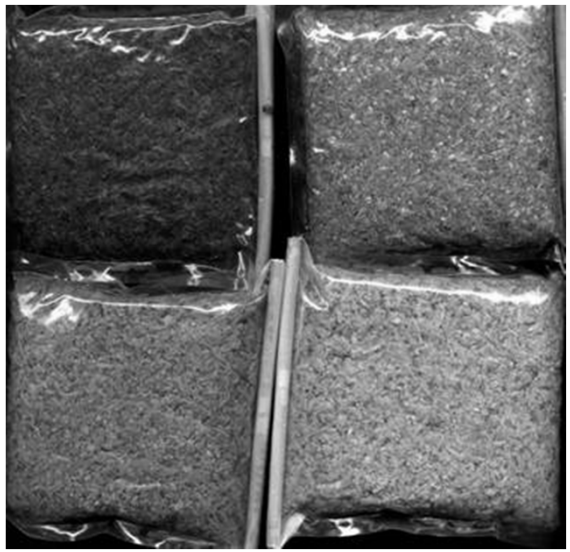
- Soybean meal
  - 2 common types
    - Dehulled, solvent extracted
      - 48% min CP; 3.5% max fiber
    - Solvent extracted
      - 44% min CP; 7% max fiber



- Often negative connotation
  - Potential for flatulence and loose stools

Plant Proteins

- Distillers grains
  - Also called distillers dried grains with solubles (DDGS)
  - Byproducts of ethanol and fructose production
  - Produced from dry milling
  - Color will vary
    - Very dark color indicative of over-processing (heat)



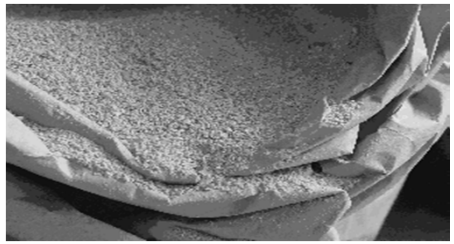
Plant Protein Sources

- Advantages
  - Less expensive
  - Readily available
  - Good quality AA profile (soybean meal)
  - Less variable in composition vs. animal sources
  - Eliminates risk of some diseases
    - Spongiform encephalopathy
      - Cattle and sheep
      - Humans
      - Cats

Plant Protein Sources



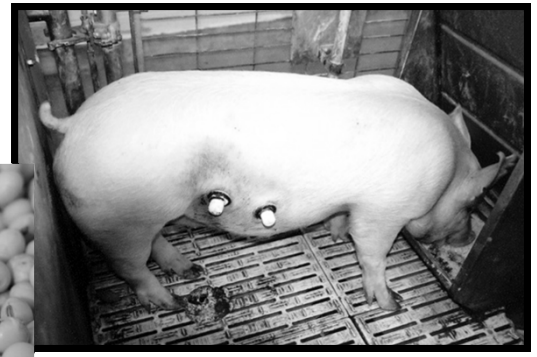
- Disadvantages
  - Anti-nutritional factors
    - Lectins, tannins, trypsin inhibitors
  - Oligosaccharides (e.g., stachyose; raffinose)
    - Flatulence
  - Dietary fiber
    - Wet fecal volume
  - Cereal grains/byproducts have poor AA profile
    - Low in lysine



Protein Sources

- What does the research say?
  - Ileal cannulated animals commonly used to test protein sources
    - Soy products
      - Whole soybeans
      - Soybean meals (low phytate; low oligosaccharides)
      - Soy protein isolates
      - Soy protein concentrates
    - Meat meals
    - Poultry meals
    - Fish proteins





Protein Sources

- What does the research say?
  - Ileal AA digestibility of soybean meal usually equal to or greater than animal sources tested
  - Total tract protein digestibility similar to animal products
    - Reason for not using soy products NOT due to ↓ AA digestibility or profile



VS



Summary

- 22 amino acids required for proper functioning of dogs and cats
  - 10 essential
  - 12 non-essential

- Protein requirement affected by:
  - Protein digestibility
  - Protein quality
  - Caloric density of diet
  - Physiological state of the animal



Summary

- Excess amino acids → fermentation → end-products
  - Some toxic in high concentrations
  - Contribute to fecal odor

- Sources of protein
  - Both animal and plant sources used
    - Beef, chicken, venison, fish, egg
    - Soybean meal, corn gluten meal
  - Byproducts of human food industry



Conclusions

- Excess amino acids provided to:
  - Account for:
    - Processing losses
    - Ingredient variability
- Use high quality protein sources in excess amounts to:
  - ↑ digestibility
  - ↓ fecal output
  - ↑ length of time between defecations

