
Fueling the Feline
Implications of high starch and fat intake when cats require dietary protein restriction
UNIVERSITY OF GUELPH
Ontario Agricultural College

Feline metabolic idiosyncracies

2x ↑ protein requirements than omnivorous species

↑ Arg requirement

↑ Met and Cys requirement

Tau is essential

Theorized to have 'carbohydrate ceiling' in terms of intake

Carbohydrate digestion and metabolism slower and lower

Require arachidonic acid within diet

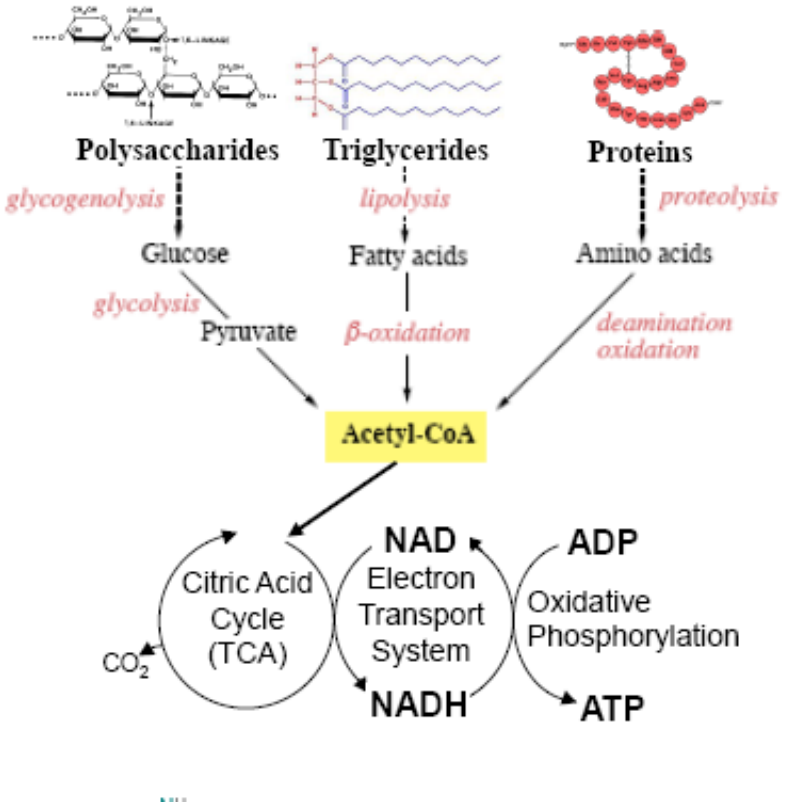
Preformed vit A, vit D, B6, B3 required

CREPUSCULAR feeding patterns

Ad libitum vs. Meal feeding patterns

Protein requirement

- Obligate carnivores cannot down regulate the enzymes that are involved in proteolysis and amino acid deamination and oxidation
- Other mammals down regulate these enzymes when they consume diets low in protein
- Kittens have ~2X the protein requirement than puppies



Protein quality

Protein quality is dependent upon:

1. **Protein content**
2. **Amino acid composition**
3. Protein digestibility and amino acid availability

compared to the requirements of the species of interest.

Protein quality without digestibility correction

DIAAS – **LIKE**

Or AA Score

$$= \frac{(\text{mg IAA / 1 g test ingredient crude protein})}{(\text{mg of same IAA / 1 g reference protein})} \text{ x } 100$$

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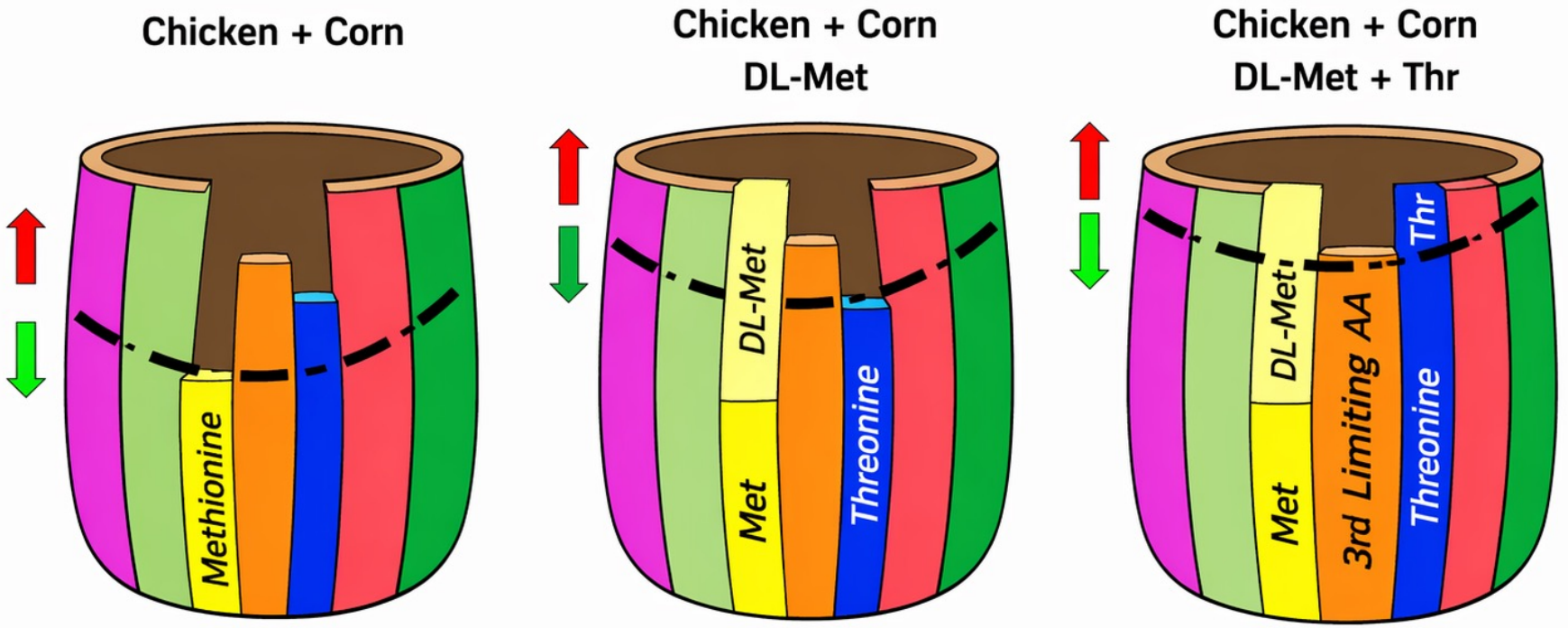
Comparing protein quality scores

	Meat Meal	Chicken Meal	Corn Gluten Meal
Arginine	164	173	70
Histidine	182	175	189
Isoleucine	167	178	270
Leucine	137	126	342
Lysine	147	172	44
Methionine	103	136	245
Cysteine	49	45	82
Phenylalanine	159	140	298
Tyrosine	119	110	251
Threonine	150	154	118
Tryptophan	75	96	63
Valine	184	170	245

The limiting amino acid theory



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Suggested minimum protein in the single format diets (% of diet on a DM basis)

	NRC[1]	AAFCO[2]	FEDIAF[2]
Cats			
Adult maintenance	20%	26%	25%
Growth and reproduction	21.3%	30%	28/30%

[1]Presumes an energy density of 4000 kcal ME/kg

[2]Presumes typical MER of 100 kcal * kg $BW^{0.67}$

*NRC Recommended allowance for adult cats for maintenance= 4.96 g/kg $BW^{0.67}$)

Let’s check our math

If we feed an ideal weight adult cat (5 kg as an example) to its energy requirement, would they meet their protein requirement being fed 20% CP (4,000 kcal ME/kg)?

100 kcal * kg $BW^{0.67}$

= 293 kcal ME

~73 g of food providing 14.7 grams of CP

CP requirement of lean adult cats =4.97 g * kg $BW^{0.67}$

= 14.6 grams of CP

Protein: Formulation guidance

- When you are formulating low protein diets, you must ensure that your digestible amino acid intakes are met
- To achieve this you can use protein sources that are highly digestible and of good quality, which are generally animal based ingredients
- Using plant-based ingredients requires multiple ingredients to be used to "compliment" the amino acid profile OR the use of individual amino acids to ensure that all indispensable amino acid requirements are met or exceeded
- Taurine only found in animal-based ingredients and should always be considered in cat diets

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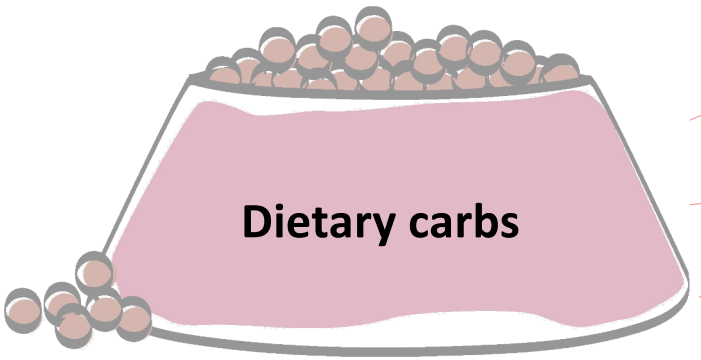
Dietary carbohydrates



- **Energy**
  - quick source
- **Texture**
  - palatability
- **Fiber**
  - fermentability
  - GI health

Classes of carbohydrates

Sugars

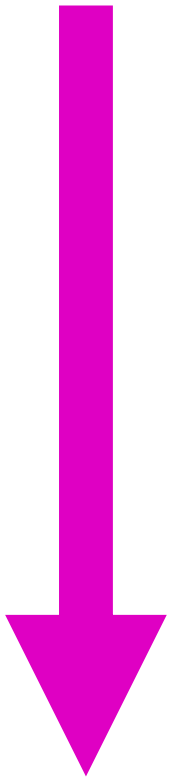
- Glucose, fructose, galactose

Complex Carbohydrates

- From cereal grains

Fibers (resistant starch)

- Indigestible plant material



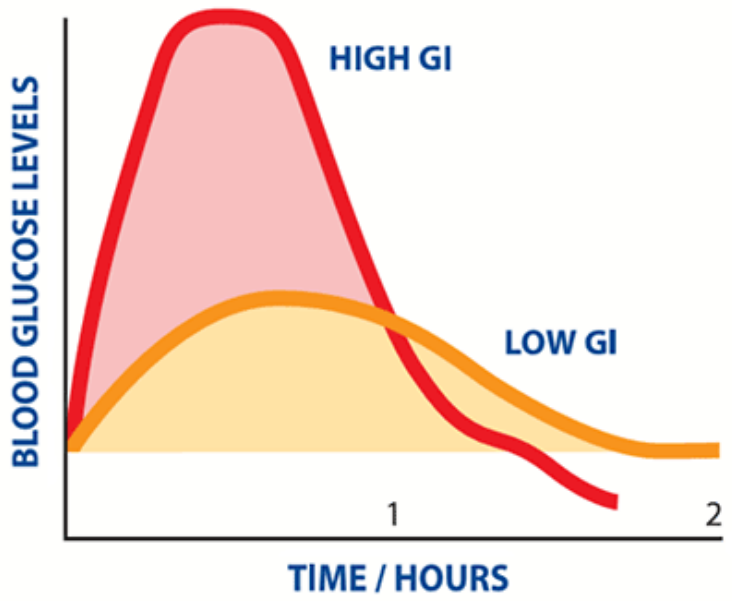
Decreasing impact on blood glucose as carbohydrate complexity increases.

Both the rate of appearance of glucose and the total impact on blood glucose diminishes as complexity increases.

Fiber reduces blood glucose due to the impact of dietary fiber on the gut environment in addition to lower glucose availability.

The physiological response to ingestion of different ingredients

- Rapidly digested starch has high post-prandial glucose (and insulin) peak compared to slowly digested starch
- In human literature carbohydrates are ranked using the glycemic index

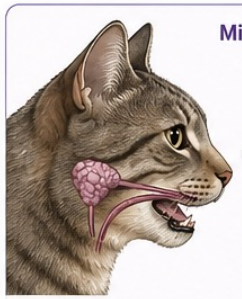


The amount of carbohydrate in the reference and test food must be the same.

Limited Capacity for Carbohydrate Digestion and Utilization in Cats

1. Digestion of Carbohydrate

Minimal salivary α-amylase

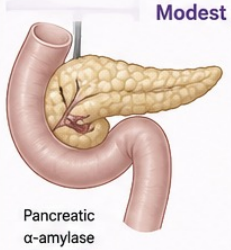


Starch

α-amylase (very low)

Little to no starch breakdown in the mouth

Modest pancreatic α-amylase



Pancreatic α-amylase (modest)

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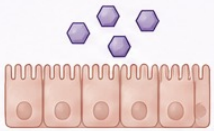
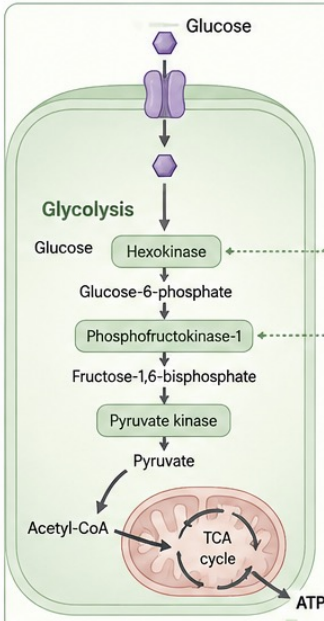
Limited starch hydrolysis to glucose

Result of Digestion

Less dietary carbohydrate is digested and absorbed as glucose compared to omnivores.



2. Cellular Utilization of Glucose



Hepatic glucokinase: low

- Low Km (low affinity)
- Low Vmax (low capacity)
- Limited induction by high carbohydrate intake

Other glycolytic enzymes: limited regulation

- Minimal allosteric regulation
- Limited hormonal response
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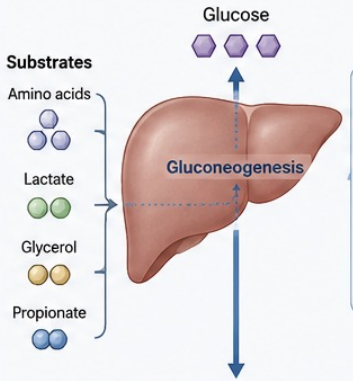
Result of Cellular Utilization

Reduced capacity to remove glucose via glycolysis, even when carbohydrate is available.

3. Reliance on Gluconeogenesis

Cats rely on gluconeogenesis even in the fed state.



Maintains blood glucose for:

- Brain
- RBCs
- Medullary renal tissue
- Other obligate glucose users

Why?

- Limited glycolytic capacity
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- Need to maintain stable blood glucose

Result of Whole-Body Metabolism

Carbohydrate is a poor source of energy. Cats depend on endogeneus production of glucose to meet metabolic needs.

Overall Consequence

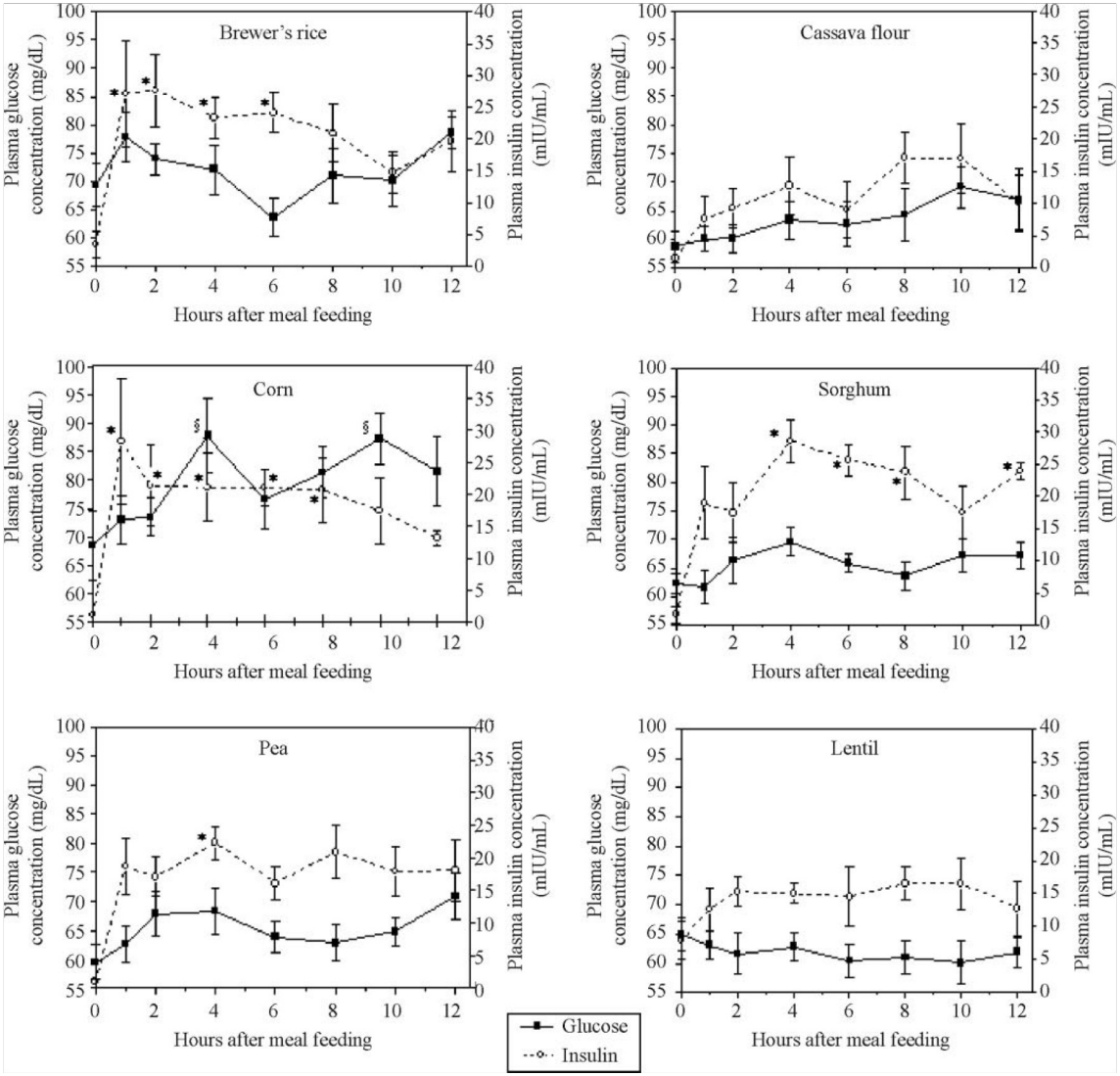
Cats have limited capacity to digest dietary carbohydrate, reduced ability to utilize glucose through glycolysis, and therefore rely heavily on gluconeogenesis to maintain blood glucose and support essential tissues.

Implications

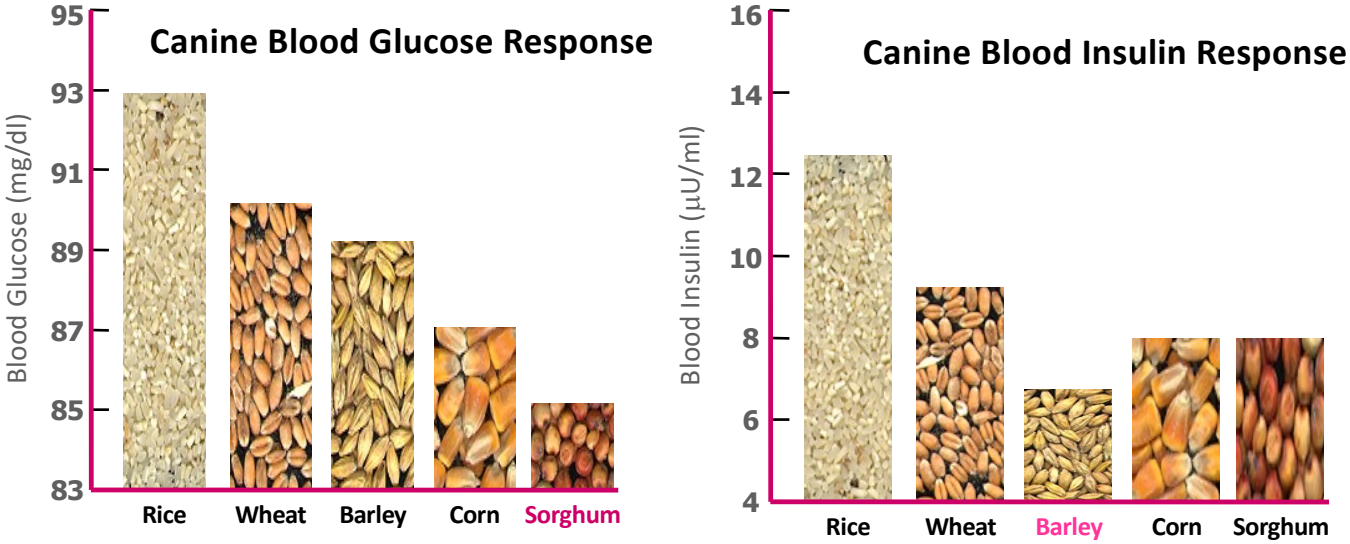
- ↑ Protein requirement (gluconeogenic amino acids)
- ↓ Carbohydrate tolerance (limited utilization)

Starch sources for cats

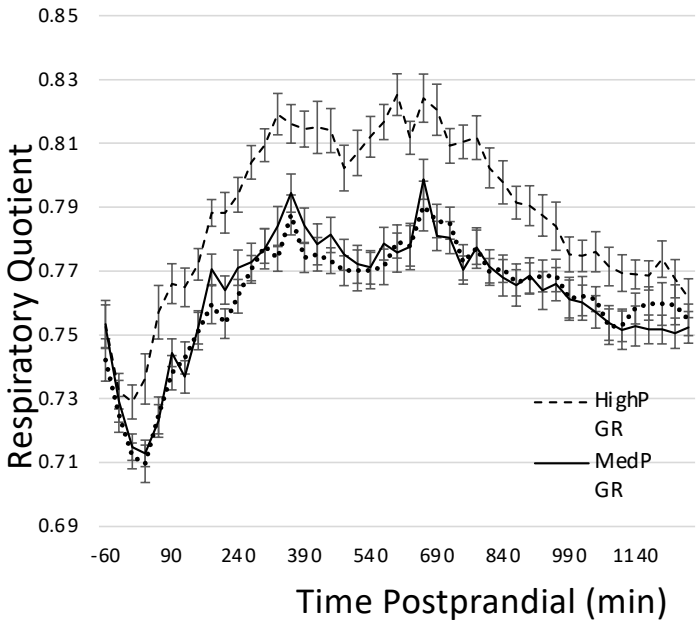
De-Oliveira et al. JAS, 2008; 86: 2237.



Starch sources: iAUC in dogs



Cats burn more glucose when higher glycemic ingredients are used



Item	HighPGR	MedPGR	LowPGR
Moisture, %	7.16	6.76	5.31
Ash, %	6.36	6.31	6.38
CP, %	38.02	35.86	42.06
Ether extract, %	15.7	22.2	22.9
Crude Fat, %	10.83	20.02	20.42
NFE, %	34.1	29.5	23.6
Starch, %	36.75	30.72	23.56
Crude fiber, %	1.17	1.78	2.58
ADF, %	1.88	2.95	2.43
NDF, %	7.36	12.58	10.57

Asaro et al. 2019 PLOS ONE

Cats adapt metabolism to dietary provision of starch and fat and when protein is equal on an energy basis

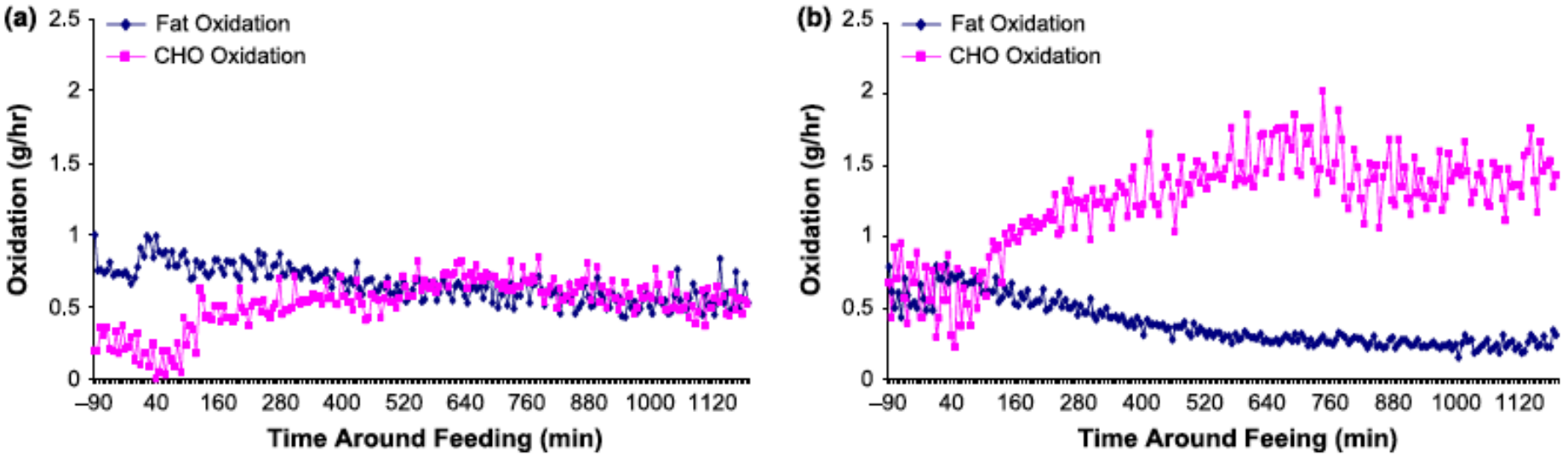


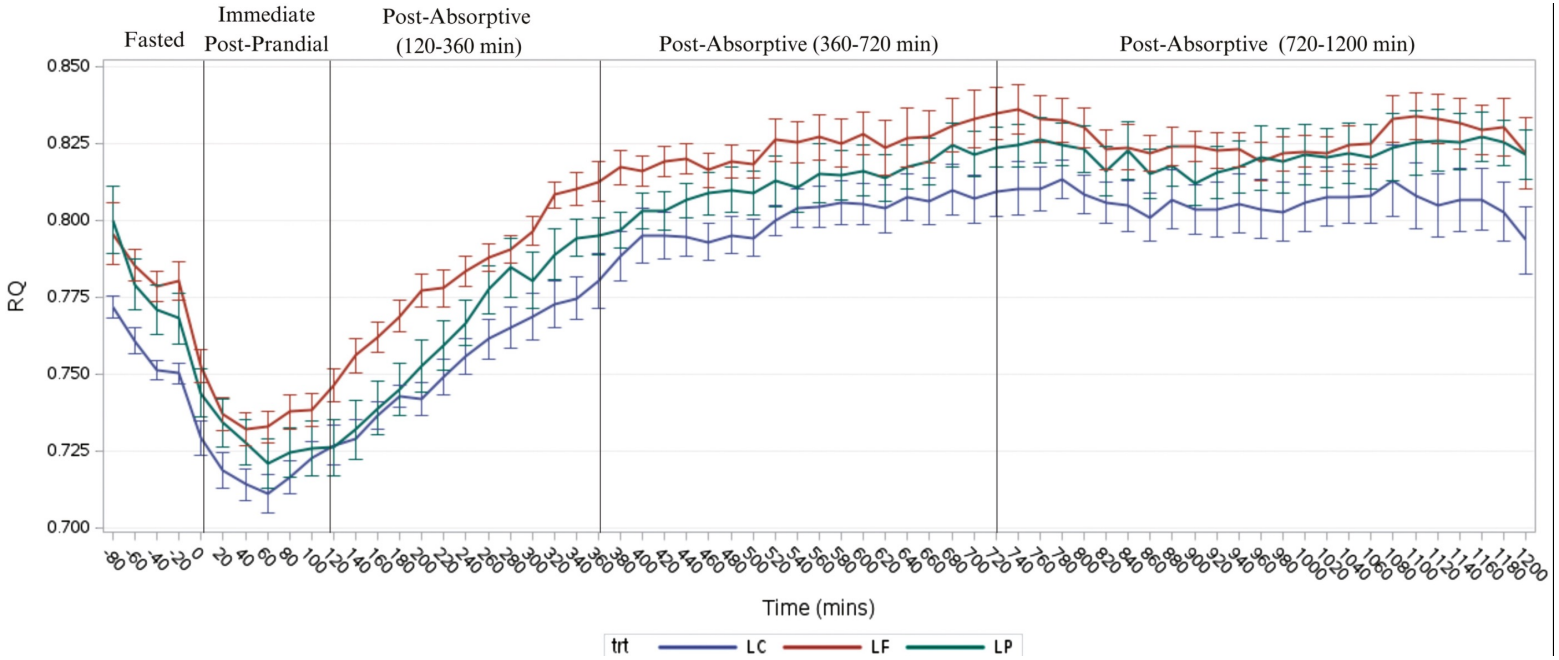
Fig. 2 Mean ($N = 10$) fat and carbohydrate oxidation measured in grams oxidized/hour during the fasted, fed and extended post-prandial states over a 20-h period in cats consuming a high-fat (a; 30% fat) and high-carbohydrate (b; 10% fat) diet during chronic (Day 13) dietary exposure.

Gooding, Flickinger, Atkinson, Duncan, Shoveller. 2013. Effects of high-fat and high-carbohydrate diets on fat and carbohydrate oxidation and plasma metabolites in healthy cats. JAPAN. DOI: 10.1111/jpn.12126

Journal of Animal Science, 2025, **103**, skaf081
https://doi.org/10.1093/jas/skaf081
Advance access publication 11 March 2025
Companion Animal Nutrition

Isoenergetic reduction of dietary macronutrients modulates respiratory quotients and heat increment of feeding but not energy expenditure in cats

Hannah Godfrey,[†] Anna Kate Shoveller,[‡] Janelle Kelly,[‖] Darcia Kostiuk,[‖] Jennifer Saunders Blades,[‖] and Adronie Verbrugghe[§]



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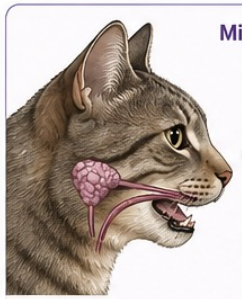

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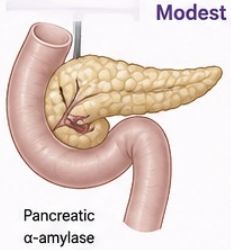

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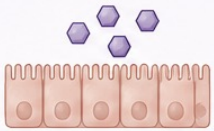

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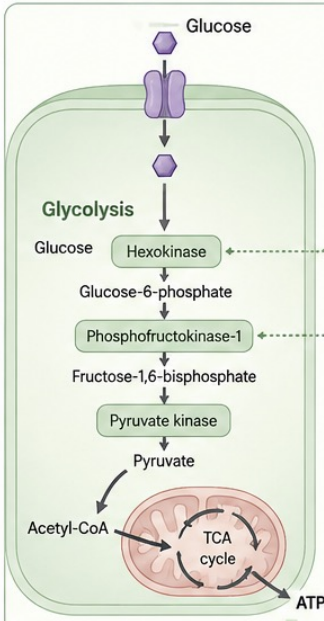

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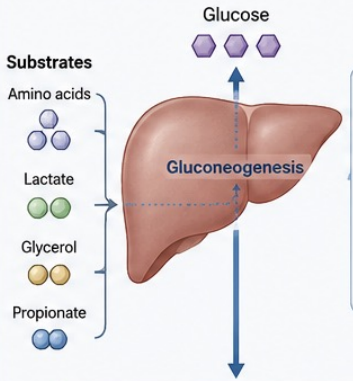

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Implications

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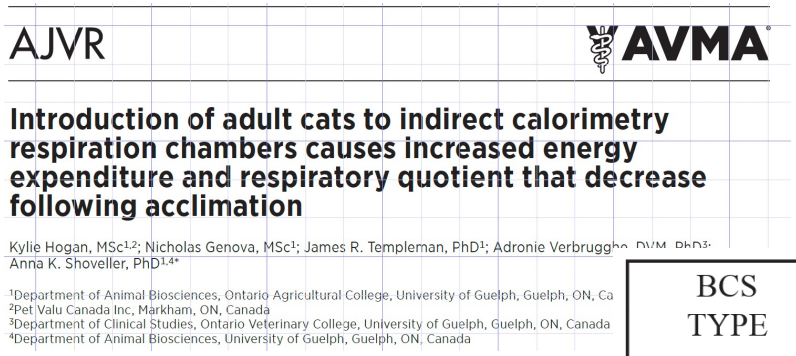
Cats, as obligate carnivores have lower RQ and level of adiposity alters macronutrient partitioning



AJVR AVMA

Introduction of adult cats to indirect calorimetry respiration chambers causes increased energy expenditure and respiratory quotient that decrease following acclimation

Kylie Hogan, MSc[1,2]; Nicholas Genova, MSc[1]; James R. Templeman, PhD[1]; Adronie Verbrugghe, DVM, PhD[3]; Anna K. Shoveller, PhD[1,4*]

[1]Department of Animal Biosciences, Ontario Agricultural College, University of Guelph, Guelph, ON, Ca
[2]Pet Valu Canada Inc, Markham, ON, Canada
[3]Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON, Canada
[4]Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada

BCS TYPE	Variable	Test			Control		
		Time	Mean	SEM	Mean	SEM	P value
Lean/Ideal	Respiratory quotient	fasted	0.736	0.006	0.741	0.007	NS
		0-870 min	0.832	0.005	0.828	0.003	NS
	Energy Expenditure	fasted	55.84	5.86	49.69	3.43	NS
		0-870 min	46.30	1.90	45.76	1.33	NS
Moderately Overweight	Respiratory quotient	fasted	0.747	0.010	0.780	0.012	NS
		0-870 min	0.820	0.002	0.833	0.004	0.033
	Energy Expenditure	fasted	43.71	1.67	50.49	4.46	NS
		0-870 min	38.93	3.02	34.90	1.20	NS

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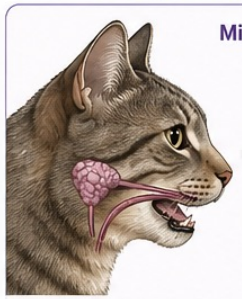

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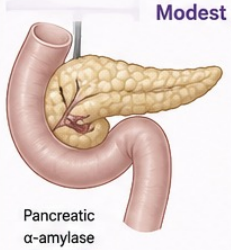

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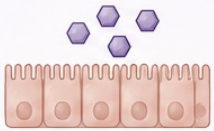

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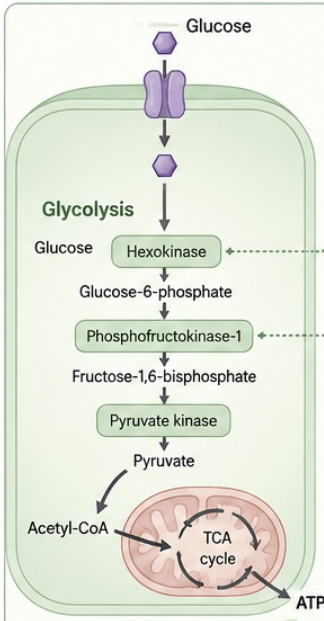

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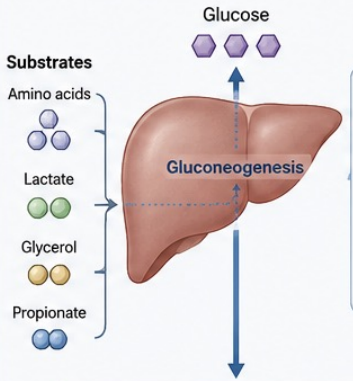

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Increasing dietary CP, or decreasing carbohydrate, results in increases in all types of energy available to the cat

Diet	23CP	25CP	26CP	29CP	36CP	41CP	SED	Linear P
GE (kcal/d)	299^{abc}	292^{a}	296^{ab}	300^{abc}	312^{c}	308^{bc}	5.07	<0.01
DE (kcal/d)	153^{a}	166^{ab}	169^{ab}	180^{b}	223^{c}	201^{bc}	24.0	<0.01
ME (kcal/d)	119^{a}	124^{ab}	129^{b}	130^{b}	170^{d}	148^{c}	20.8	0.02
NE (kcal/d)	89^{a}	95^{b}	115^{bc}	121^{c}	140^{d}	123^{c}	19.9	0.01

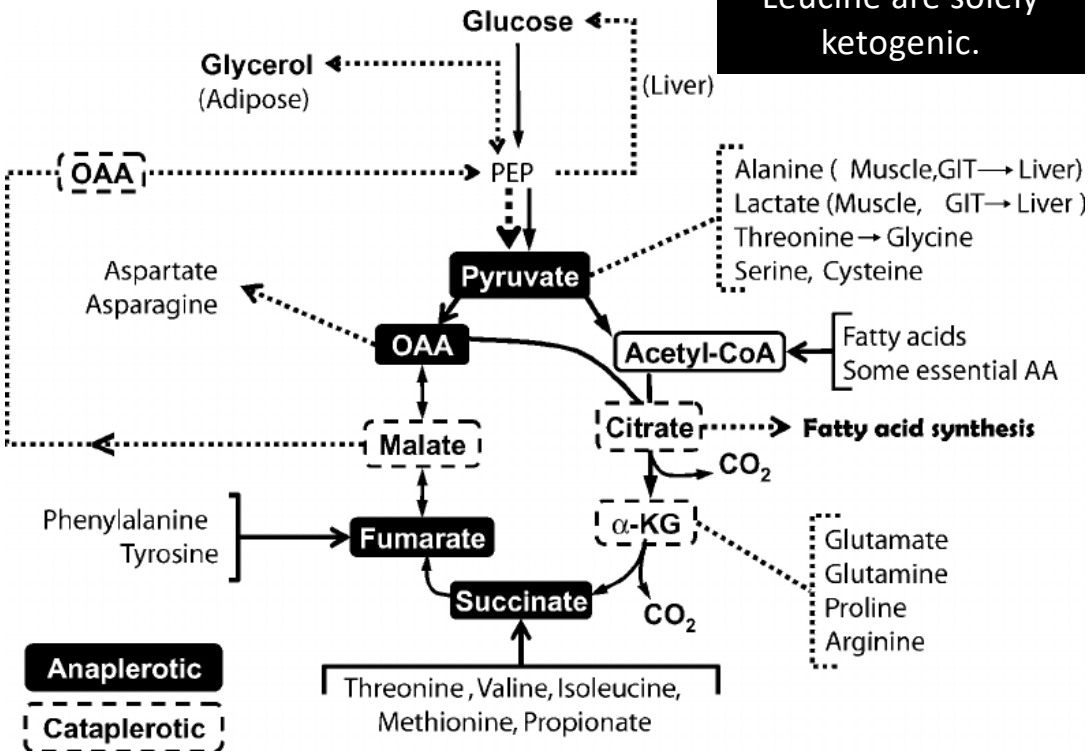
petcurean

NSERC CRSNG

Glucose is precious and mostly self made, fundamentally affecting fuel use and energy metabolism

1) Cats have low hepatic glucokinase and limited regulation of other glycolytic enzymes
2) Cats have minimal salivary amylase and modest pancreatic amylase
3) Cats rely on gluconeogenesis, even in the fed state*
4) Protein and amino acids become the main substrate for glucose production, which is energetically costly *
5) Fat is preferred and rapidly used *

Only Lysine and Leucine are solely ketogenic.



Bequette et al. 2006. Application of stable isotopes and mass isotopomer distribution analysis to the study of intermediary metabolism of nutrients. Journal of Animal Science. 10.2527/2006.8413_supplE50x

Carbohydrates: Formulation guidance

- Dietary carbohydrates are digested and absorbed differently, causing different glycemic responses and these should be considered in formulation
- Cats respond to changes in dietary carbohydrates and fat
- Lean and overweight cats have different responses to diet

Feline metabolic idiosyncracies

2x ↑ protein requirements than omnivorous species

↑ Arg requirement

↑ Met and Cys requirement

Tau is essential

Require arachidonic acid within diet

Preformed vit A, vit D, B6, B3 required

Gluconeogenic enzyme activity is upregulated

Theorized to have 'carbohydrate ceiling' in terms of intake

CREPUSCULAR feeding patterns

Ad libitum vs. Meal feeding patterns

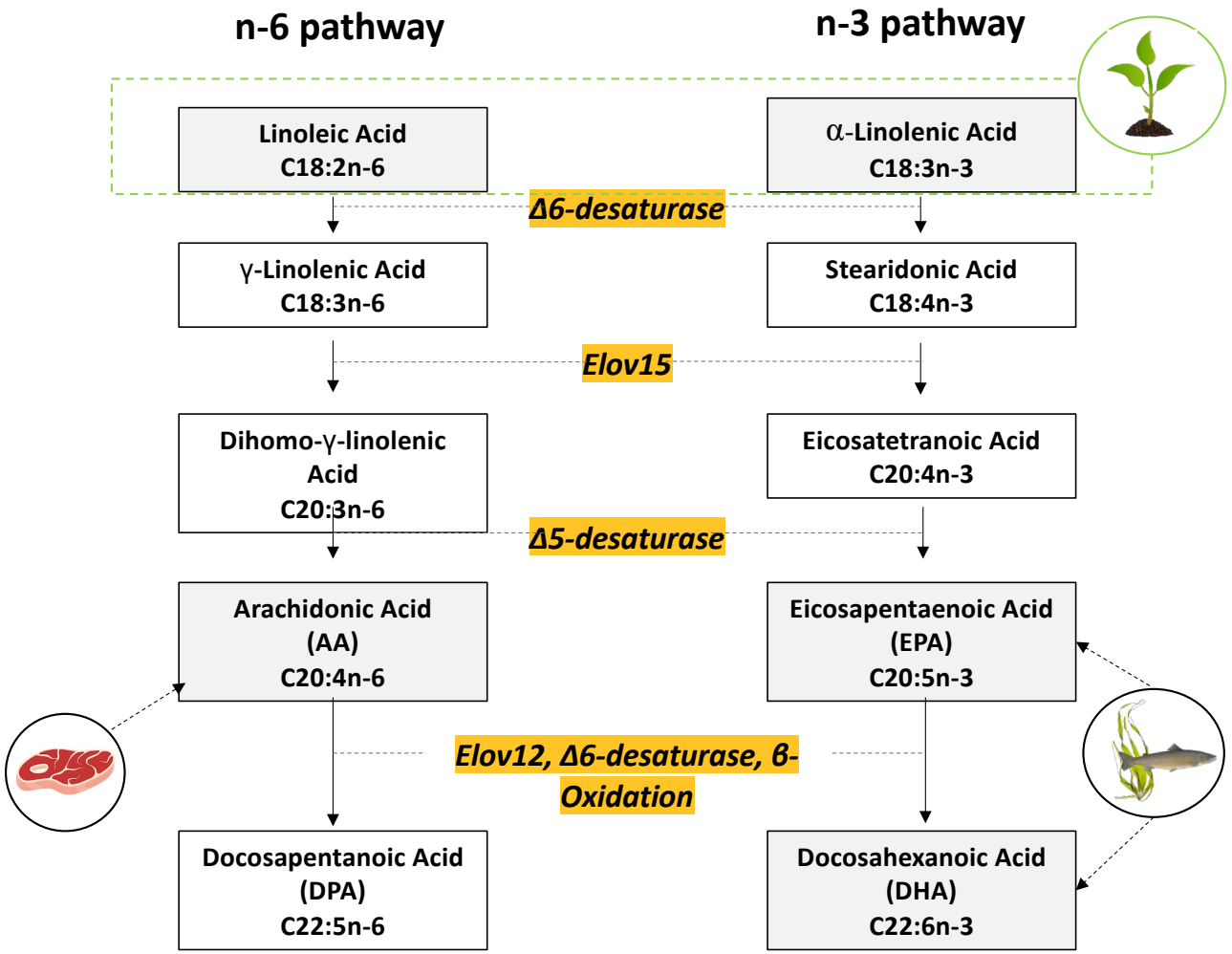
Feline fatty acid recommendations

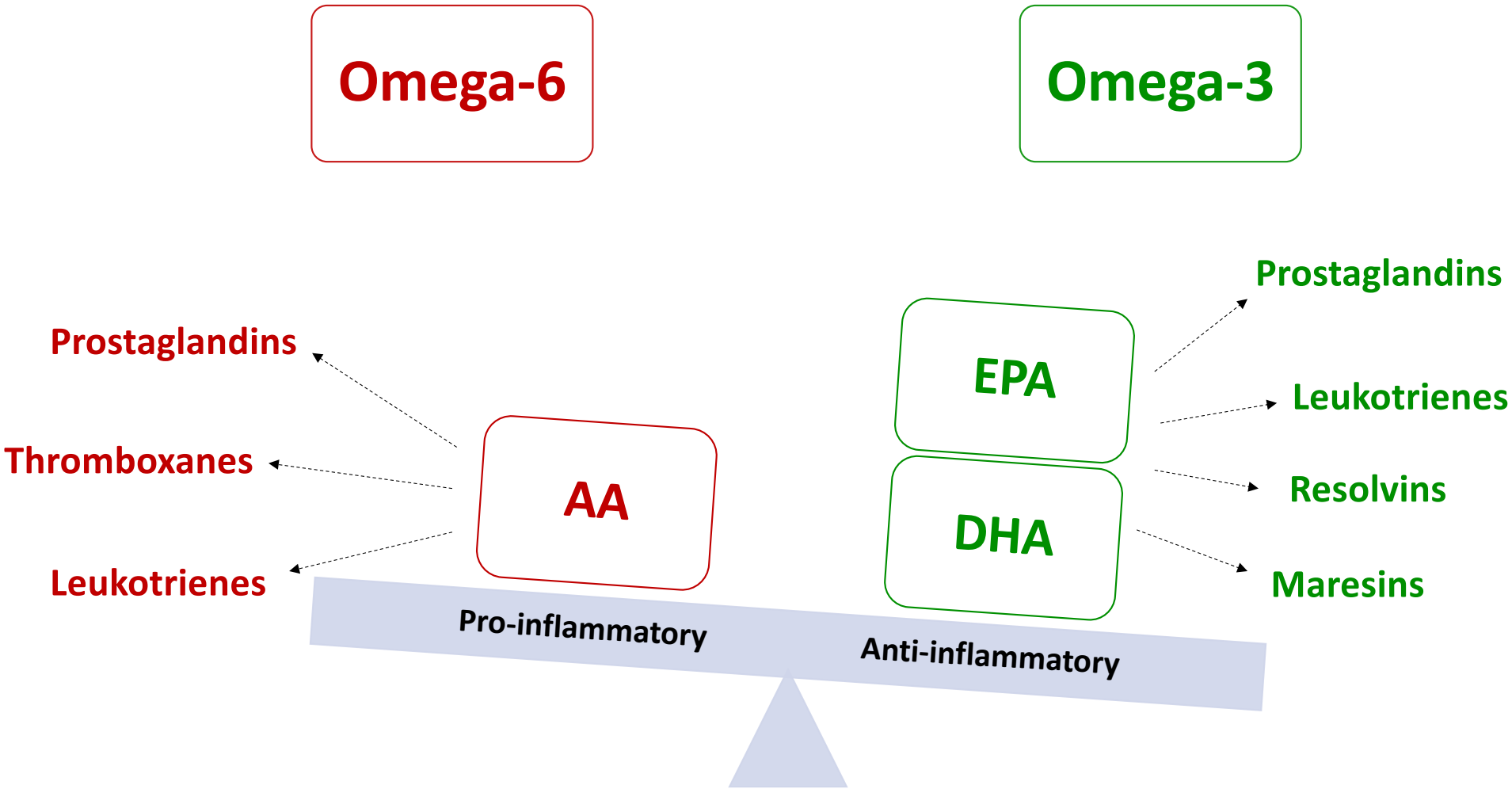
Fatty acid	AAFCO Grow/Repr	AAFCO Adult	2006 NRC Growth	2006 NRC Adult
Crude fat	9%	9%	9%	9%
Linoleic	0.5%	0.5%	0.55%	0.55%
Arachidonic	0.02%	0.02%	0.02%	0.006%
Linolenic			0.02%	NONE
EPA & DHA			0.01%	0.01%

*Kittens (NRC): EPA should not exceed 60% of total EPA and DHA

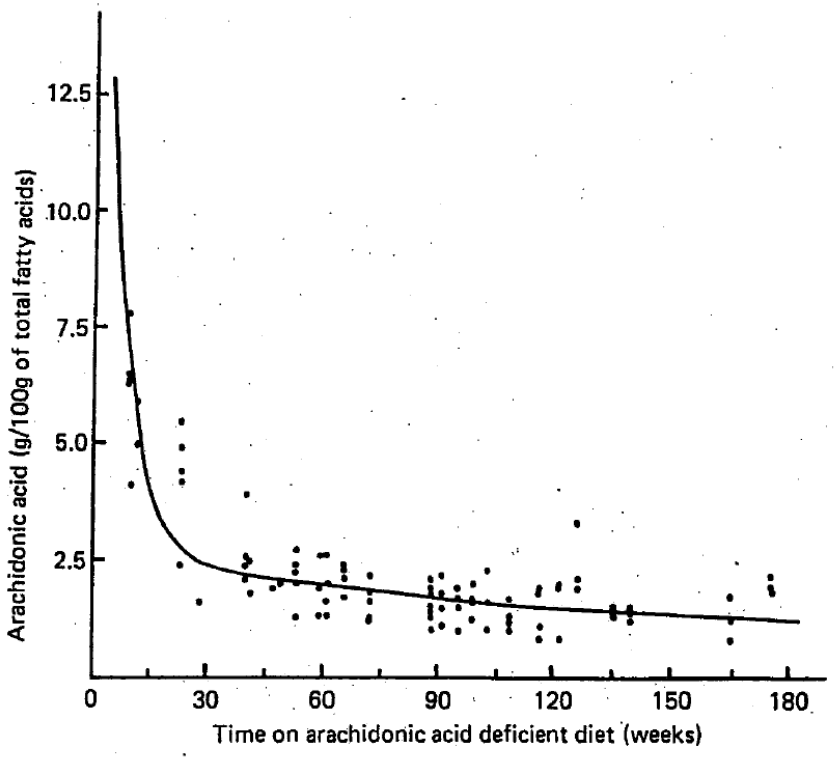
*Adults (NRC): no EPA data available; keep EPA at 20% of total EPA and DHA or below

n-6 and n-3 Fatty Acid Pathways




Omega-6
Omega-3
Prostaglandins
Thromboxanes
Leukotrienes
AA
EPA
DHA
Prostaglandins
Leukotrienes
Resolvins
Maresins
Pro-inflammatory
Anti-inflammatory

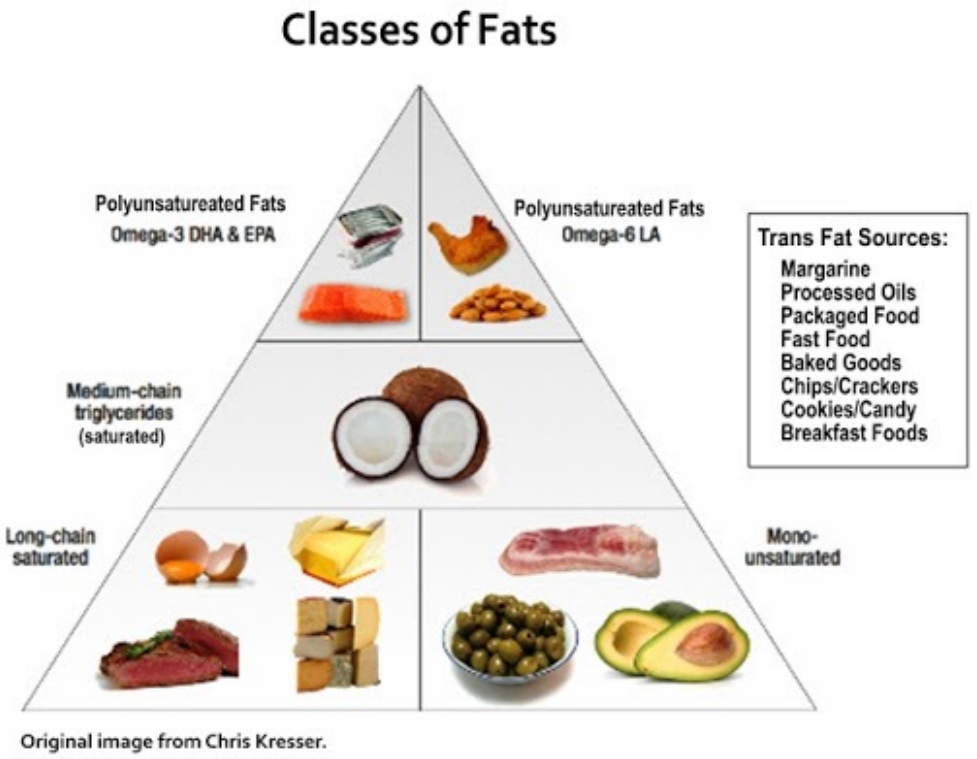
The essentiality of arachidonic acid



Decrease in the level of arachidonic acid in red blood cell ethanolamine phosphoglycerides of cats given a linoleic acid supplemented, but arachidonic acid deficient diet (after Frankel, 1980)

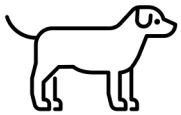
Dietary sources of fat

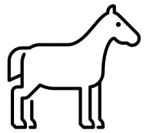
- Plant origin (oils)
  - Oilseeds – soybean, canola, sunflower
    - Medium chain length
    - Unsaturated
  - Grains – corn
  - Tropical – coconut, palm
    - Short chain length
    - Saturated
- Animal origin (fats)
  - Mammals – tallow, animal fat, pork fat
    - Medium chain length
    - Saturated and monounsaturated
  - Marine – fish oils
    - Long chain length
    - Unsaturated



Sources of fatty acids

- Linolenic acid (18:3n-3)
  - Flaxseed oil
  - Soybean oil
  - Canola oil
- Linoleic acid (18:2n-6)
  - Safflower oil
  - Sunflower oil
  - Corn oil
  - Flaxseed oil
    - Also called linseed oil
- Long-chain PUFA
  - EPA (20:5n-3)
  - DPA (22:5n-3)
  - DHA (22:6n-3)
    - Fish/marine oils
    - Algae





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The balance of n-6 and n-3 fatty acids in canine, feline, and equine nutrition: exploring sources and the significance of alpha-linolenic acid

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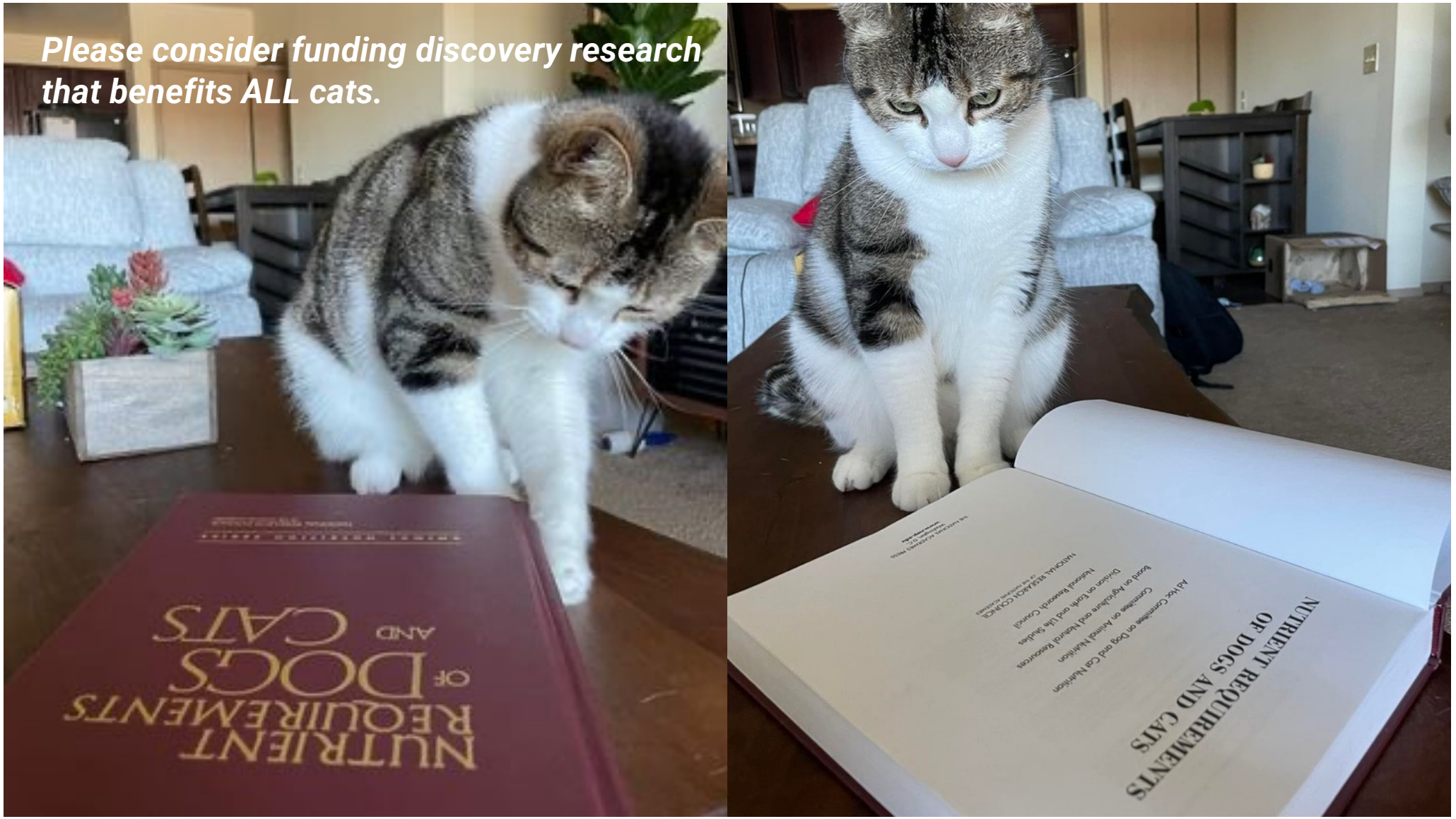
Dietary fat: Formulation guidance

- Dietary fat delivers a dense source of energy and the essential fatty acids, ALA and LA
- Puppies and kittens benefit from a source of DHA for retinal and cognitive development
- Animals with chronic inflammation benefit from a source of EPA+DHA to help resolve and reduce inflammation
- The n6: n3 ratio is also important to consider in your formulation and should be a primary consideration when deciding what you want your food to deliver

Bringing it all together

- Low protein diets need to ensure sufficient individual amino acid sufficiency and amino acid supplementation may be warranted for secondary benefits
- Consider the type of cat and the glycemic response that may occur with different ingredient sources
- Consider the type of cat and whether they are developing or their state of inflammation to determine your choice of dietary fat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