Recent Developments in Performance Horse Health and Nutrition

Joe D. Pagan, Ph.D.

Kentucky Equine Research, Inc.

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World Leaders In Equine Nutrition

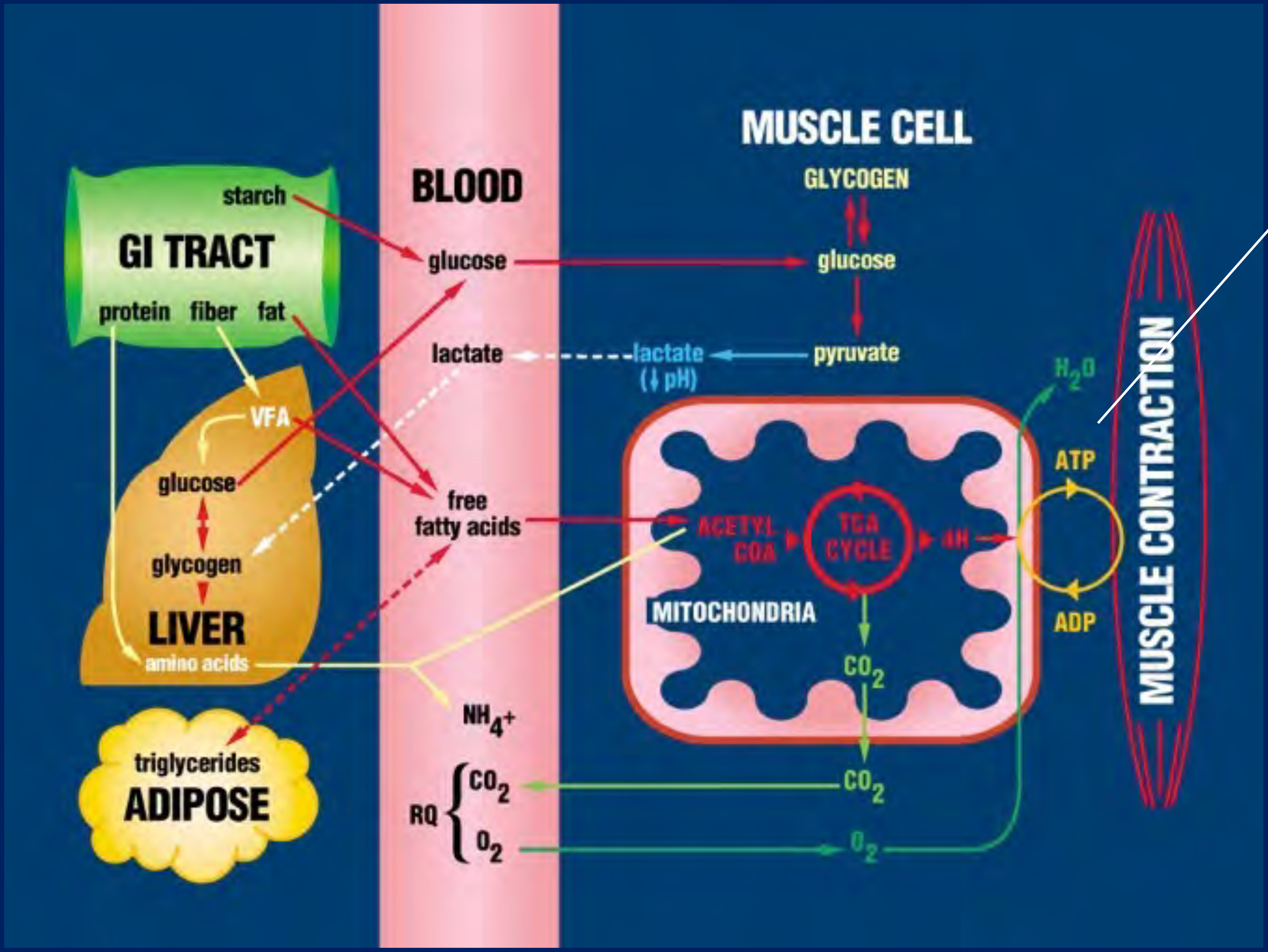

World One Dream


CINCH
JEANS
CINCH
Rancho Oso Rio

Nutrition of the Performance Horse

Energy is the nutritional factor most influenced by training and work

Energy Generation by Horse Muscle During Exercise



Adenosine triphosphate

ATP generated from:

- blood glucose
- muscle glycogen
- fat
- protein

Dietary Energy Sources

- Plant Fiber
- Non-structural carbohydrate (NSC)
  - Starch
  - Sugar
- Fat
- Protein

Dietary Energy Sources

- **Plant Fiber**
- Non-structural carbohydrate (NSC)
  - Starch
  - Sugar
- Fat
- Protein

Horse's Natural Feed is Forage

Horse evolved as wandering herbivores with voluminous hindguts adapted to process large quantities of high fiber forage.

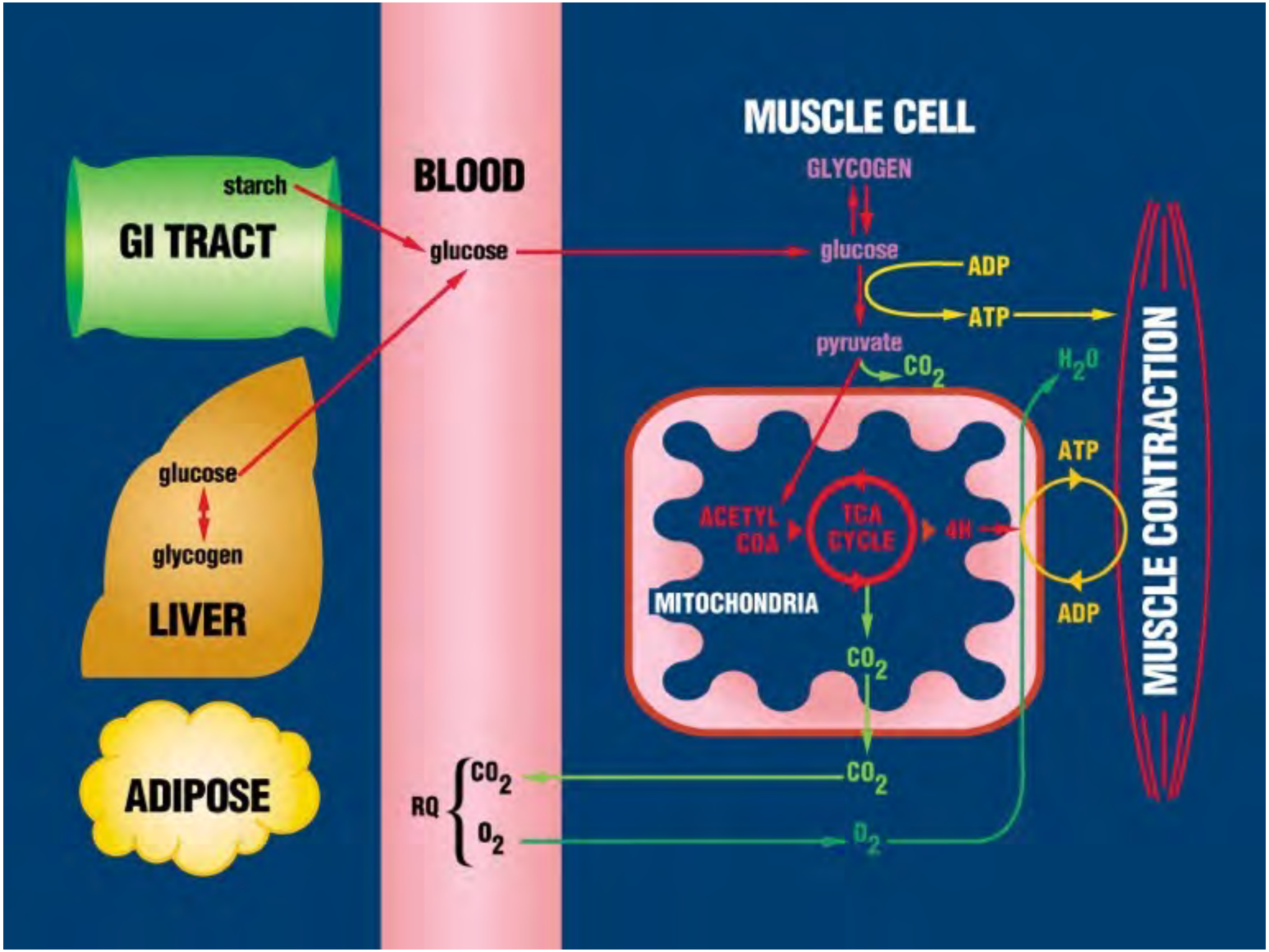
Domestication

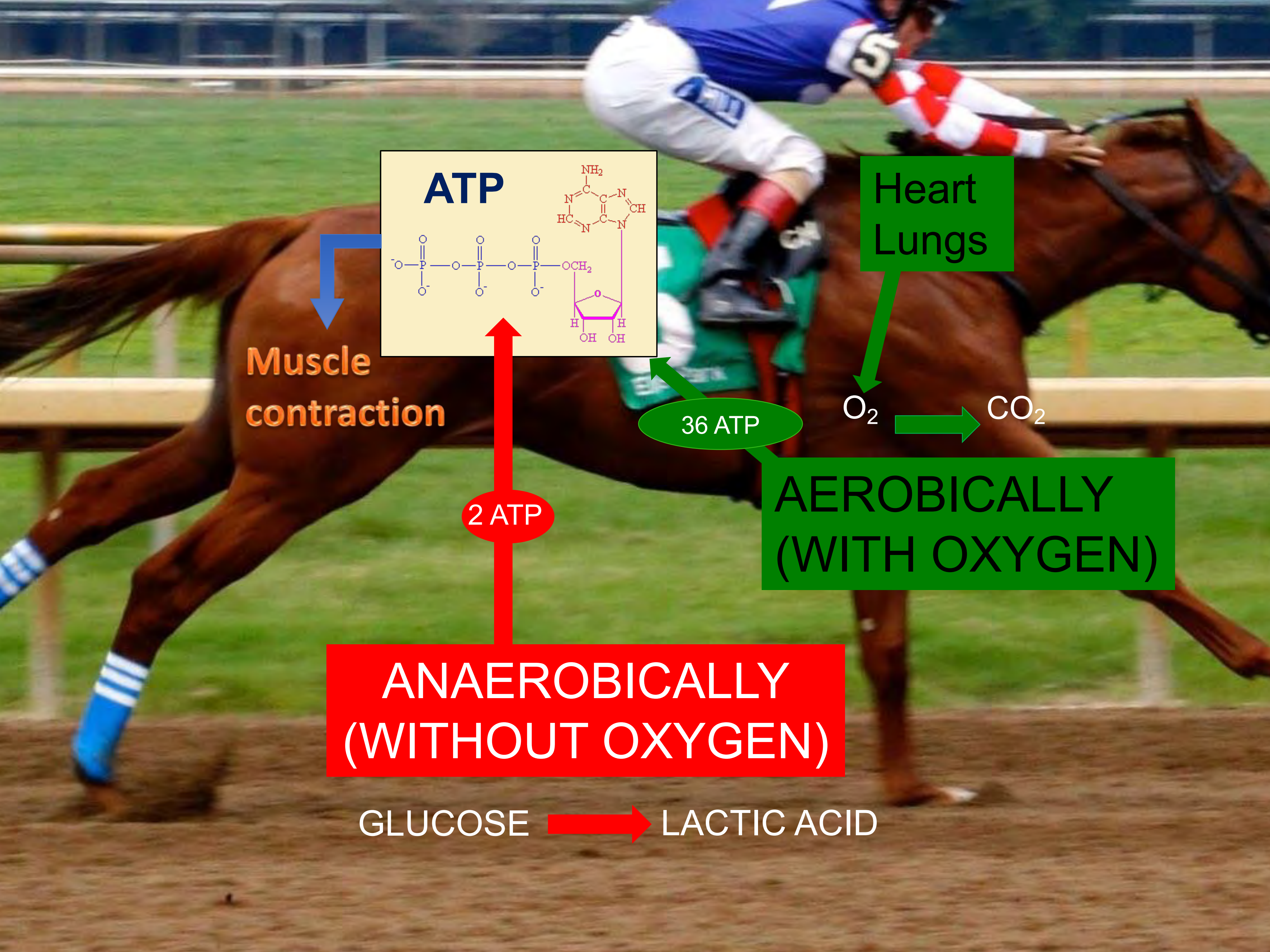
- The energy requirements of working horses could not be met by forage alone
- The deficit was met by feeding cereal grains

Dietary Energy Sources

- Plant Fiber
- Non-structural carbohydrate (NSC)
  - Starch
  - Sugar
- Fat
- Protein

Glucose is a major substrate for energy generation




ATP
Muscle
contraction
Heart
Lungs
36 ATP
O_2
CO_2
AEROBICALLY
(WITH OXYGEN)
2 ATP
ANAEROBICALLY
(WITHOUT OXYGEN)
GLUCOSE
LACTIC ACID

Non-structural Carbohydrates (NSC)

- Starch
- Water Soluble Carbohydrate (WSS)

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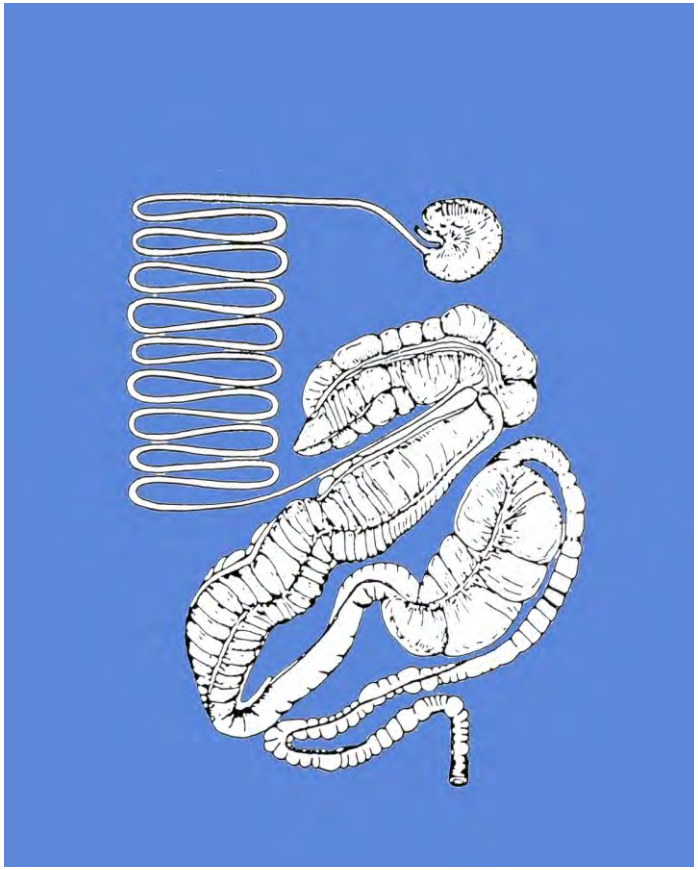
Horses are poor starch digesters

- Rapid rate of passage
- Low amylase production
- Oats>Barley>Corn
- Up to 70% of corn starch may escape prececal digestion



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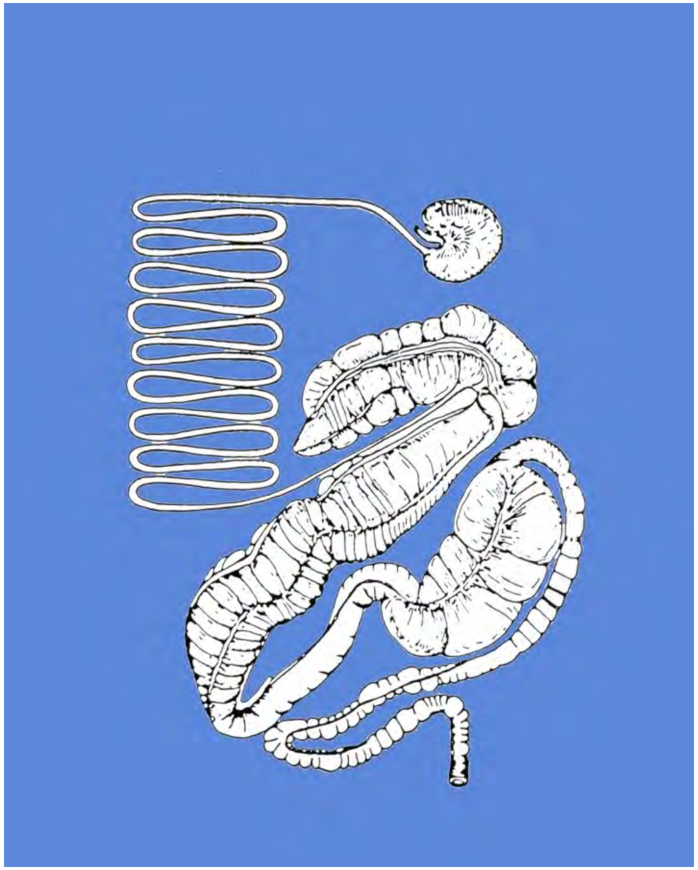
When large grain meals are fed to horses

- Starch may escape digestion in the small intestine
- Rapidly fermented in the cecum and colon
- Volatile fatty acid (VFA) and lactic acid production increases
- A significant decrease in pH
- Hindgut Acidosis (HGA)



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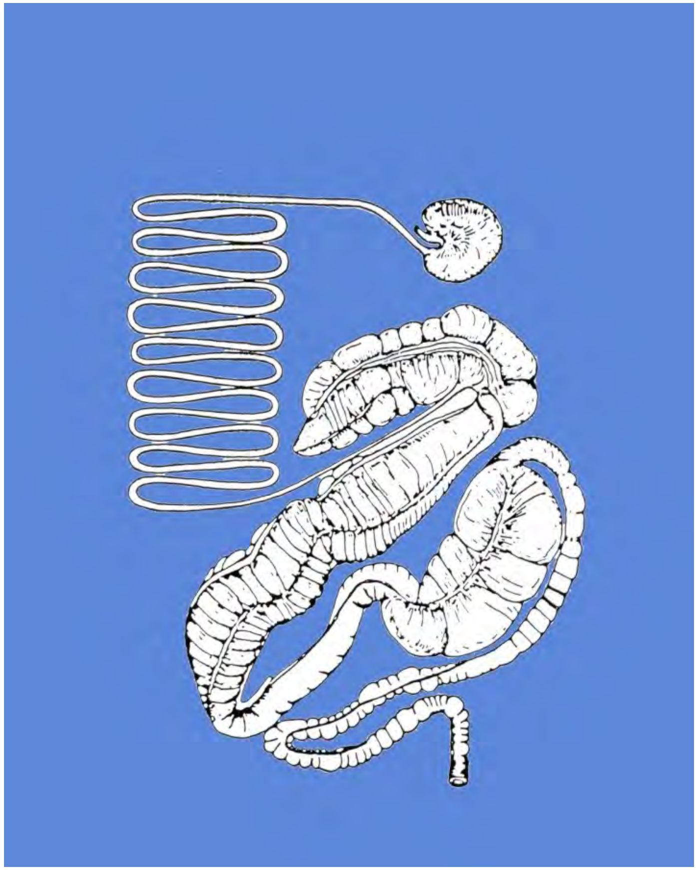
Effects of Hindgut Acidosis

- Causes irritation or damage to the intestinal mucosa
- Increases the permeability of the large intestinal mucosa to toxins and larger molecules
- Implicated in the development of equine laminitis



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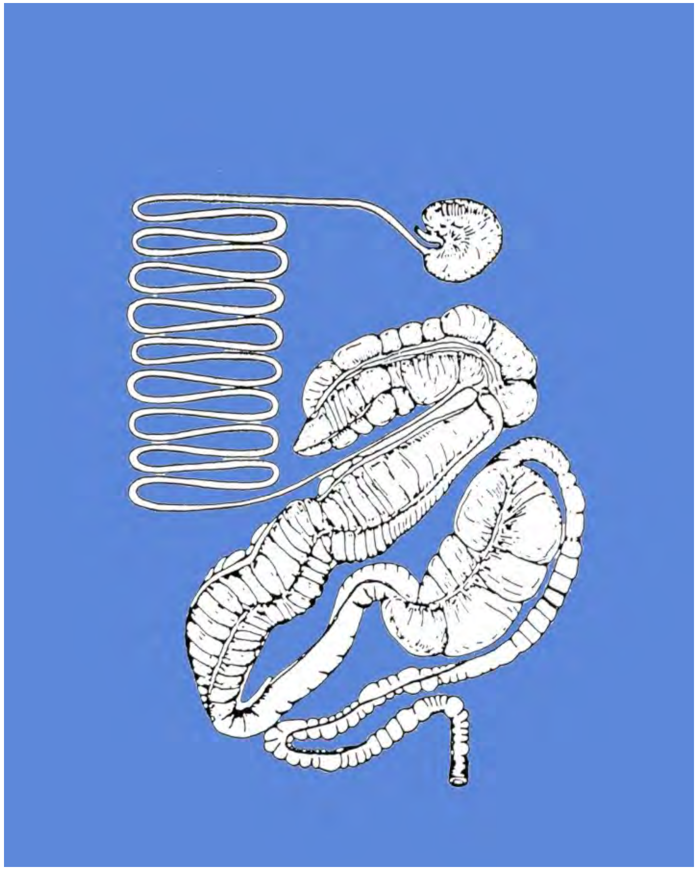
Effects of Hindgut Acidosis

- Anorexia
- Colic
- Stereotypical behaviors such as wood chewing and stall weaving



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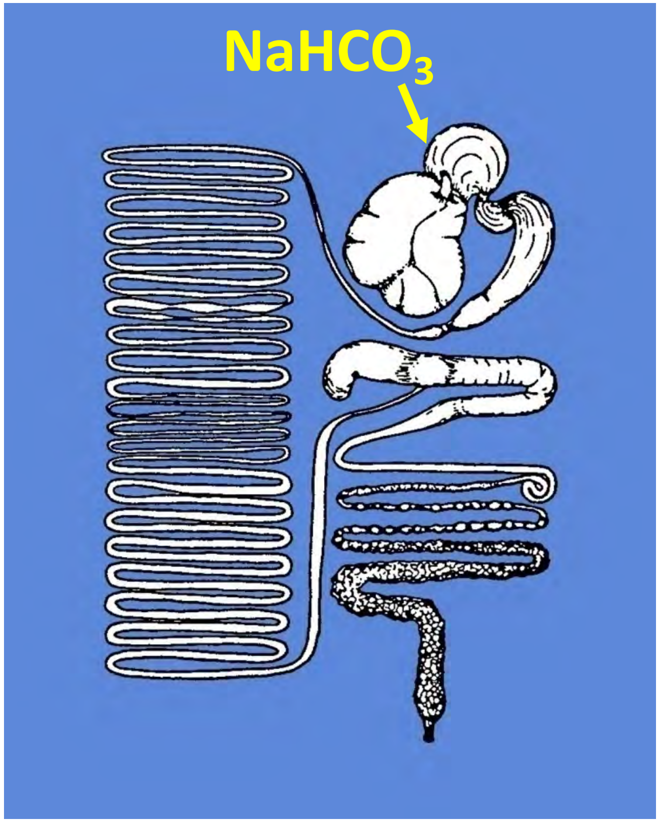
Rumen acidosis

- Common problem in dairy cattle fed high grain diets
- Sodium bicarbonate is often added to a cows ration as a buffer
- Attenuates drop in rumen pH that decreases feed intake and milk production



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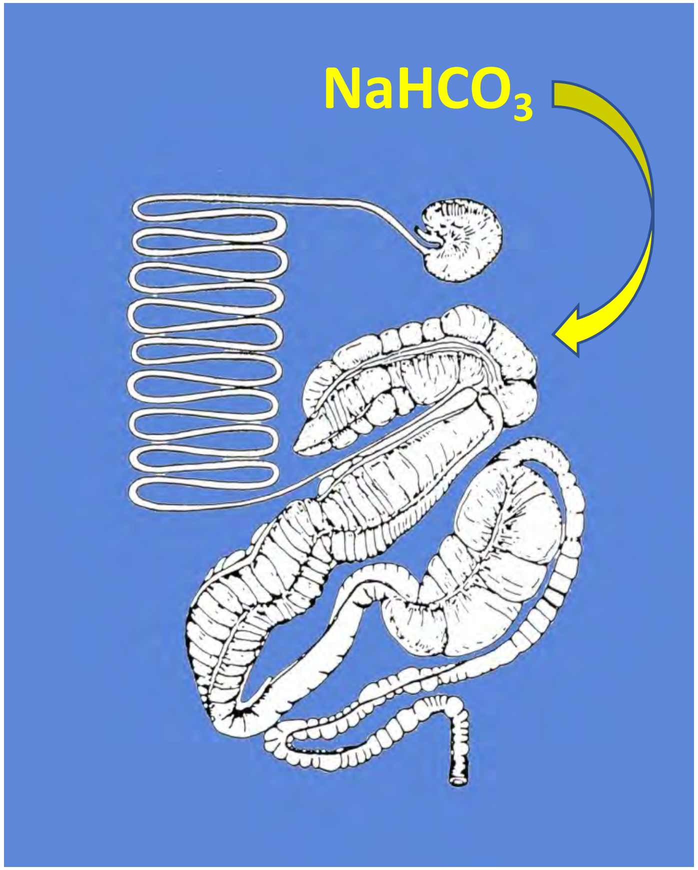
How do you deliver $NaHCO_3$ to the hindgut?

- Needs to survive acidic environment in stomach
- Needs to survive digestive enzymes in small intestine
- Needs to dissociate in the cecum and colon to provide bicarbonate to hindgut



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EquiShure®

- In partnership with Balchem, Kentucky Equine Research, Inc. developed an encapsulated sodium bicarbonate that survives transit through the stomach and small intestine of the horse

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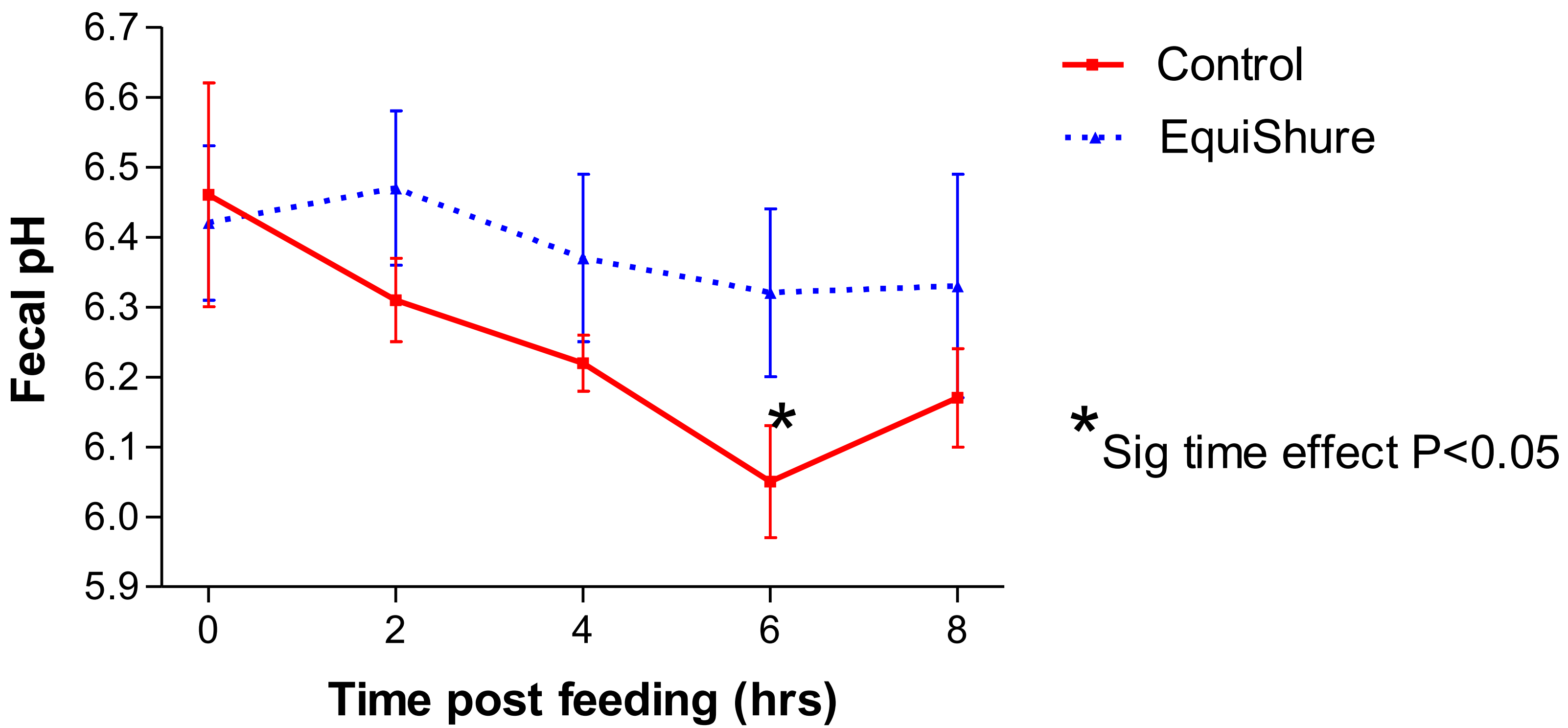
Feeding Protected Sodium Bicarbonate Attenuates Hindgut Acidosis in Horses Fed a High Grain Ration

Joe D. Pagan, PhD, T.J. Lawrence, MS and L.A. Lawrence, Ph.D.

Kentucky Equine Research, Versailles, Kentucky 40383

Presented at 2007 AAEP Convention



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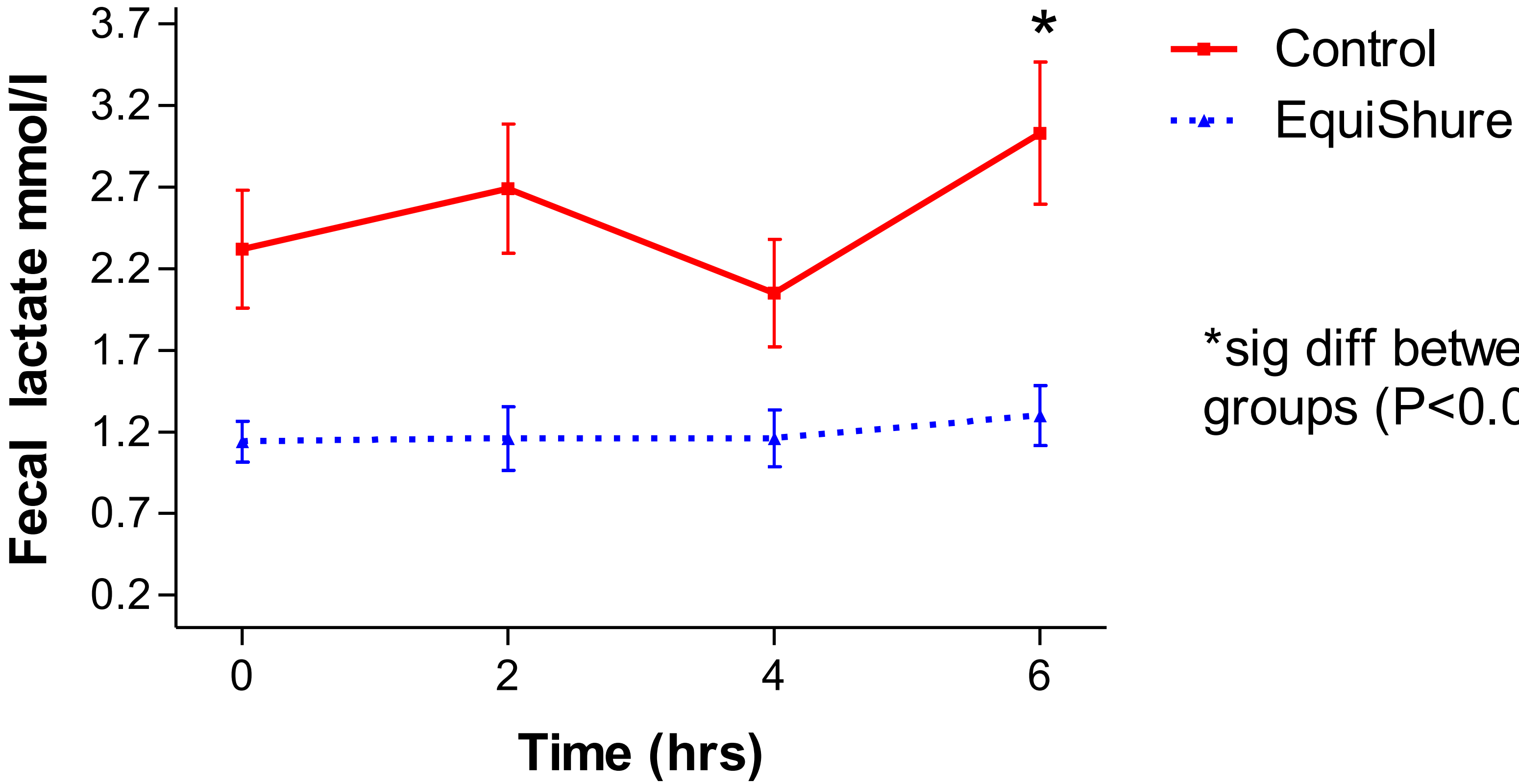
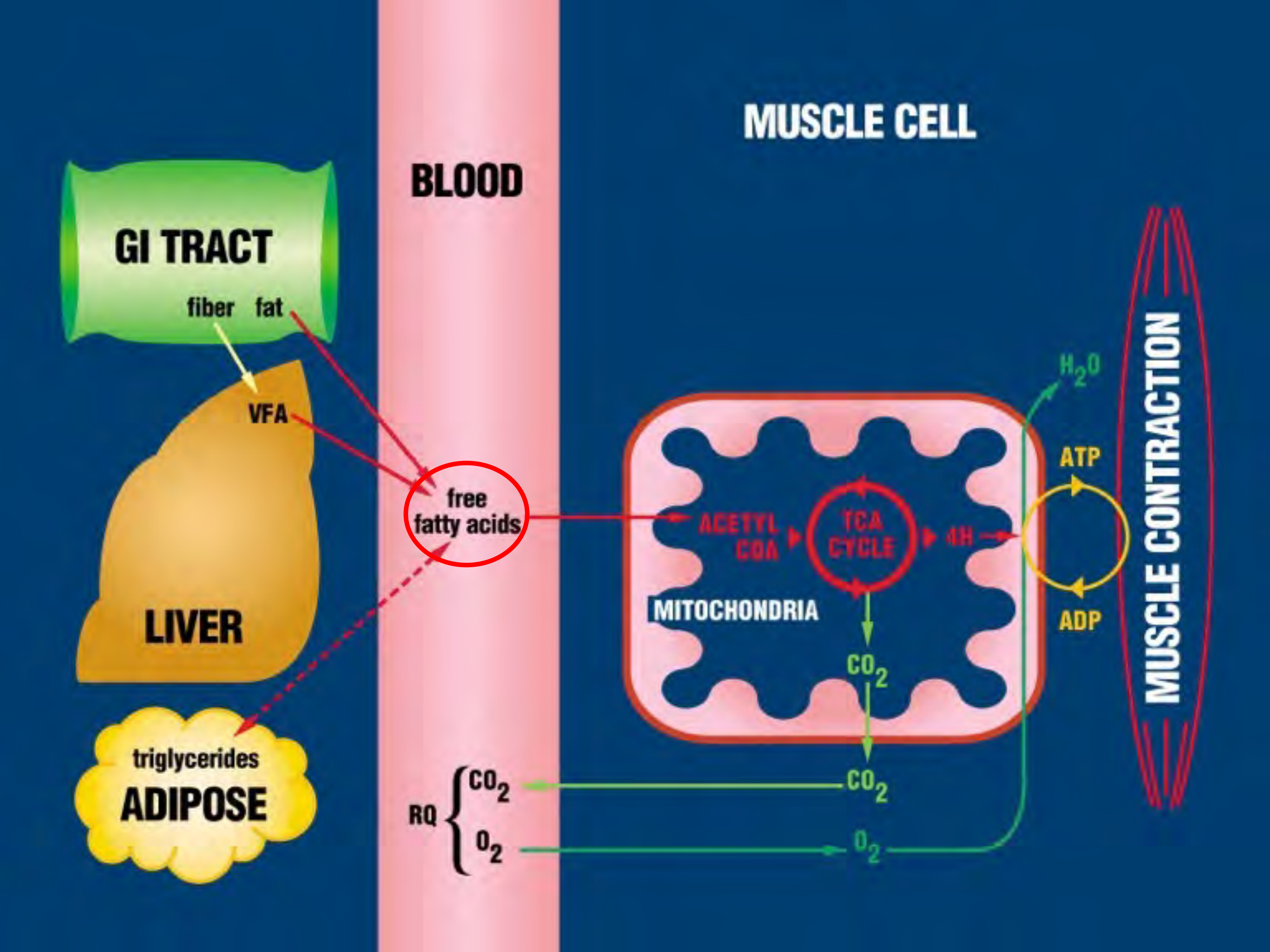


*sig diff between groups (P<0.05)

Dietary Energy Sources

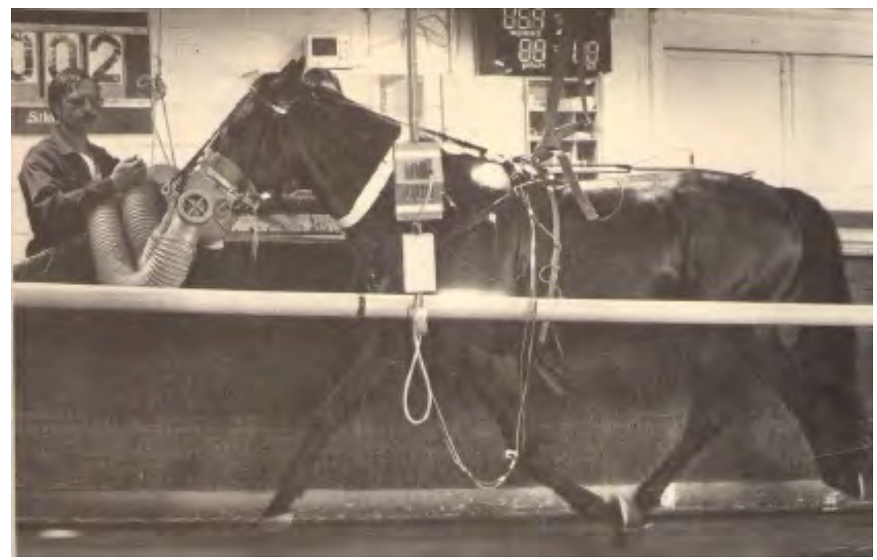
- Plant Fiber
- Non-structural carbohydrate (NSC)
  - Starch
  - Sugar
- **Fat**
- Protein


MUSCLE CELL
BLOOD
GI TRACT
fiber
fat
VFA
LIVER
free fatty acids
triglycerides
ADIPOSE
ACETYL COA
TCA CYCLE
4H
MITOCHONDRIA
CO_2
H_2O
ATP
ADP
MUSCLE CONTRACTION
RQ
CO_2
O_2
CO_2
O_2

The Effect of Dietary Energy Source on Exercise Performance in Standardbred Horses

J. D. PAGAN, B. ESSÉN-GUSTAVSSON, A. LINDHOLM,
and J. THORNTON
Department of Medicine I, Swedish University of Agricultural Sciences,
S 750 07 Uppsala, Sweden

2nd International Conference on Equine Exercise Physiology, 1986



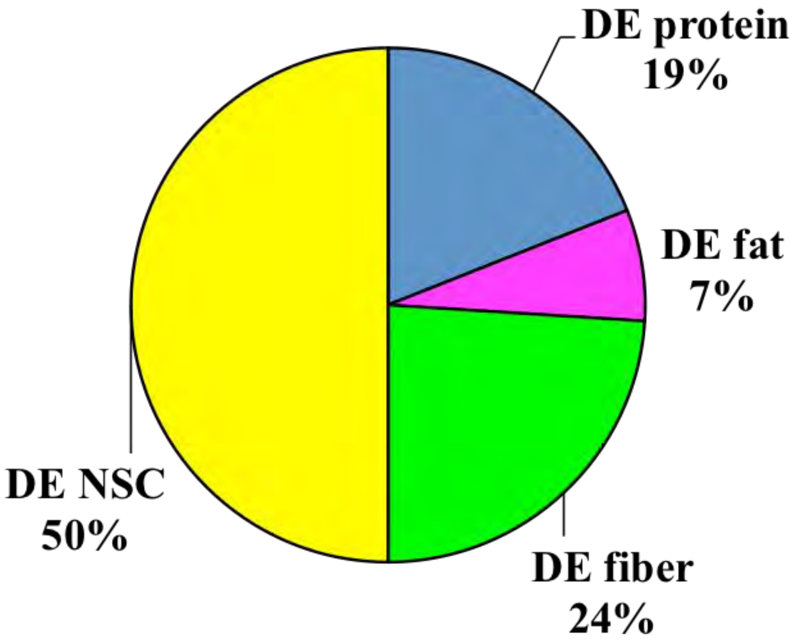
Effects of fat adaptation on glucose kinetics and substrate oxidation during low-intensity exercise

J. D. PAGAN, R. J. GEOR, P. A. HARRIS, K. HOEKSTRA, S. GARDNER, C. HUDSON, A. PRINCE

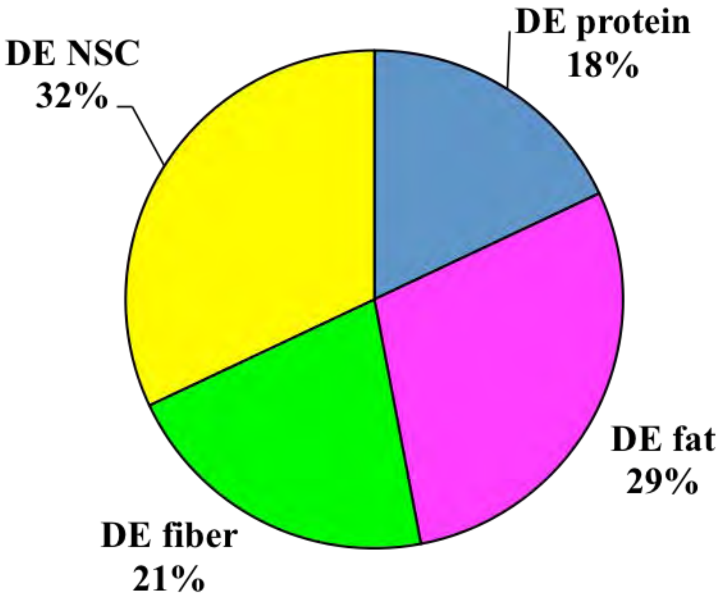
Equine Veterinary Journal

Volume 34, Issue S34, pages 33–38, September 2002

Digestible Energy Contribution



CONTROL



FAT

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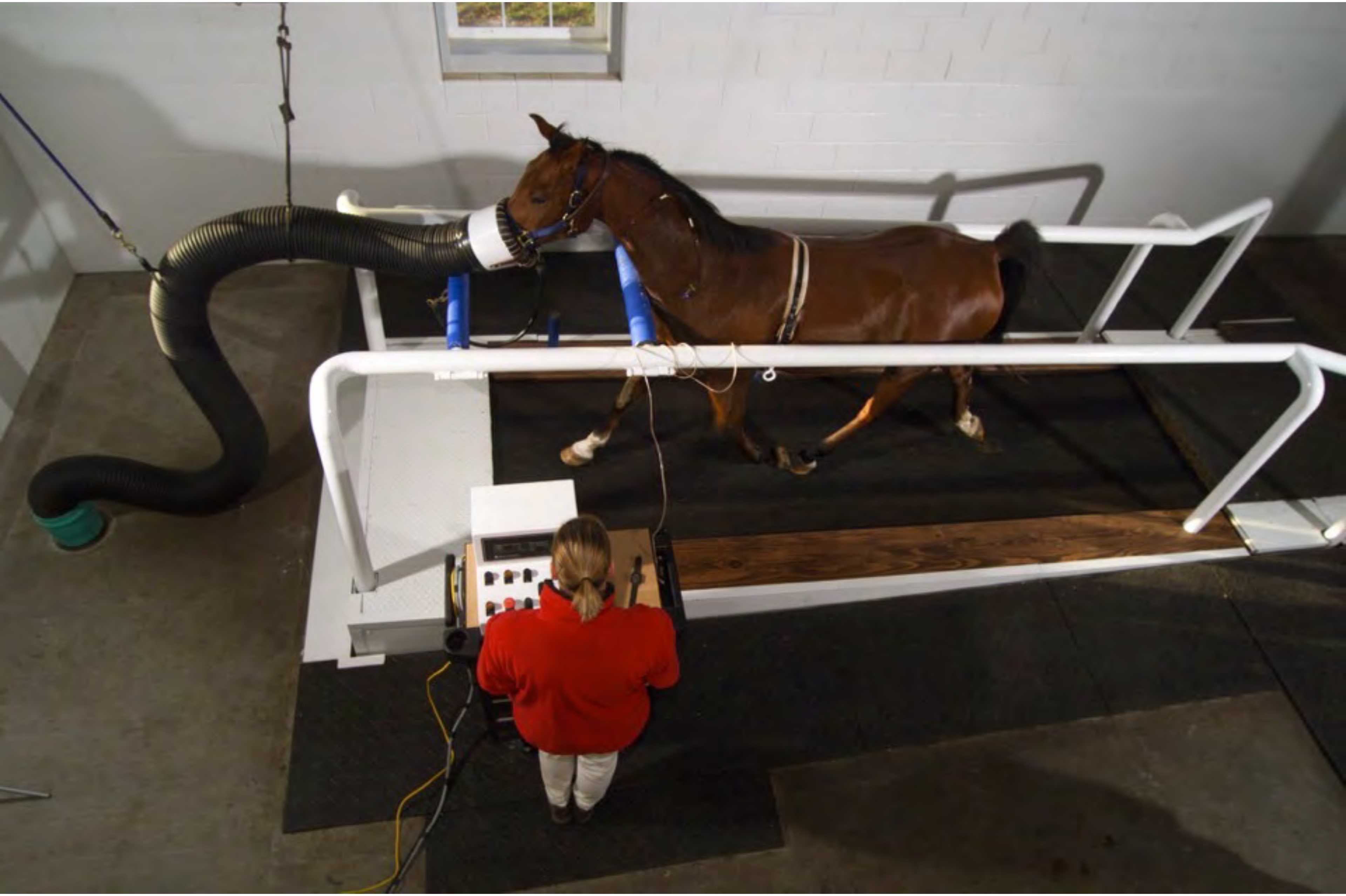
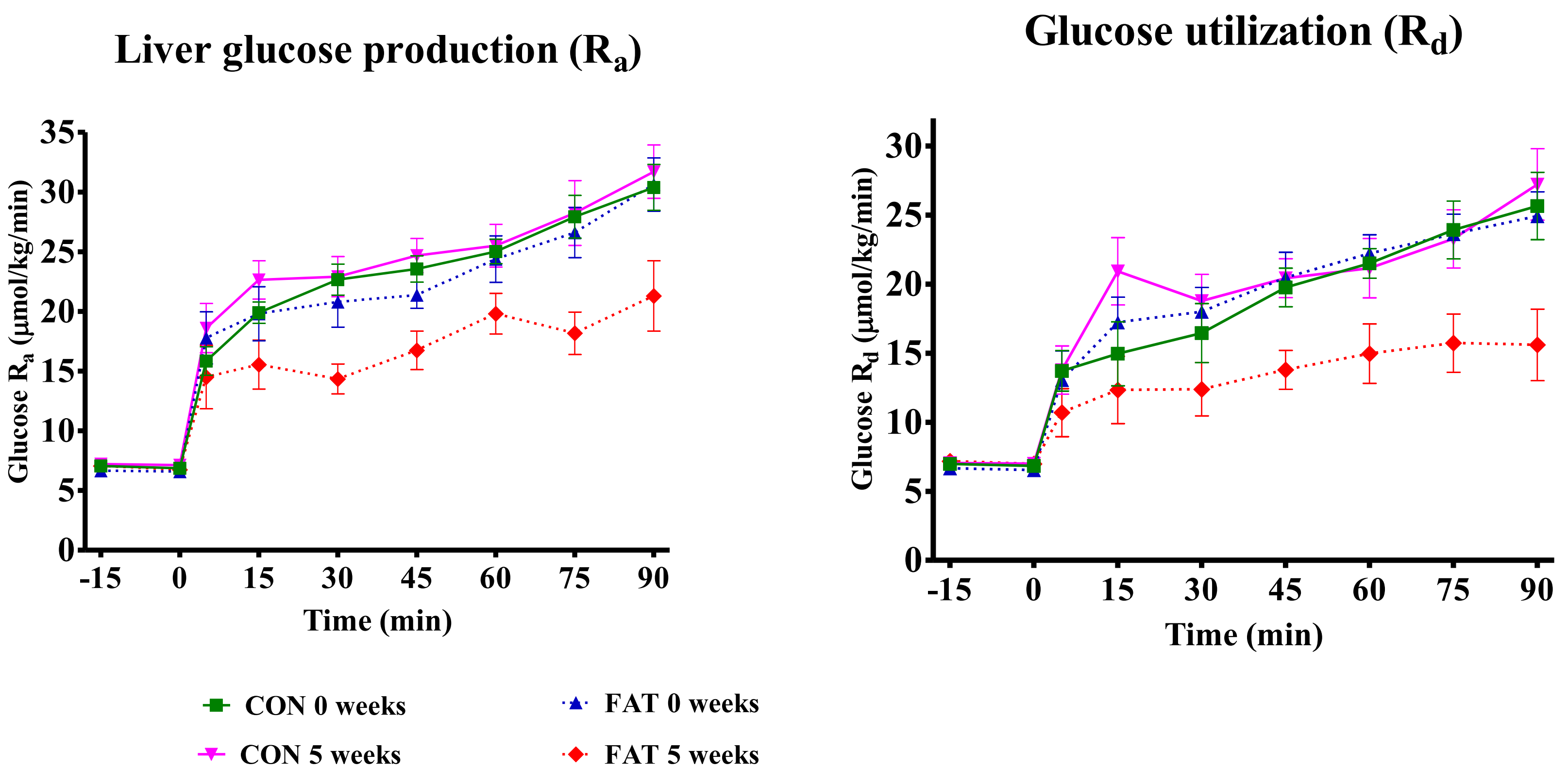
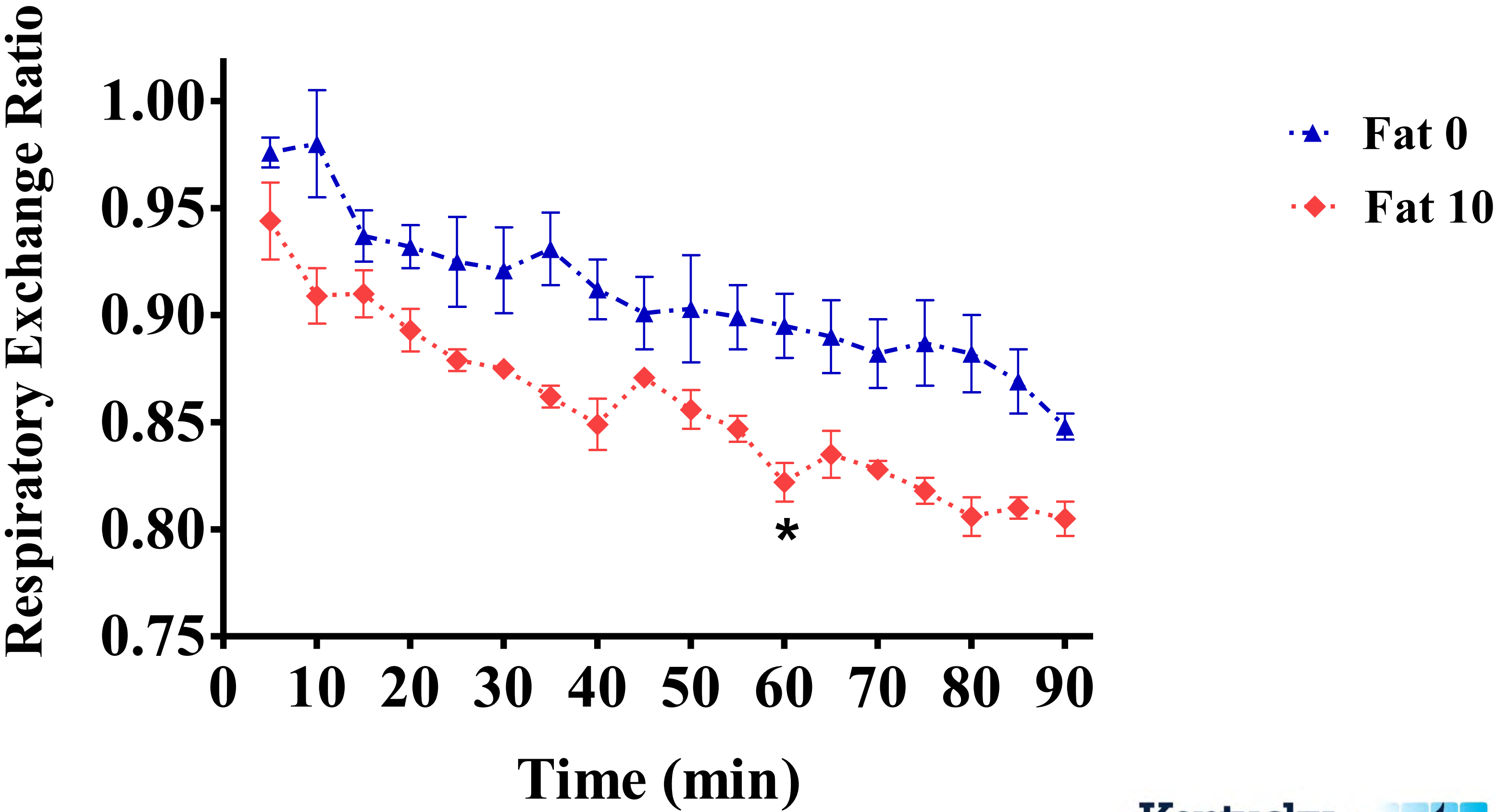


Glucose Kinetics



Respiratory Exchange Ratio



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Dietary Fat and Exercise Metabolism

- After 5 weeks on a fat-supplemented diet (30% fat calories) horses used less carbohydrate and more fat during prolonged exercise
- Implications
  - Sparing of carbohydrate desirable for horses undertaking endurance-type exercise

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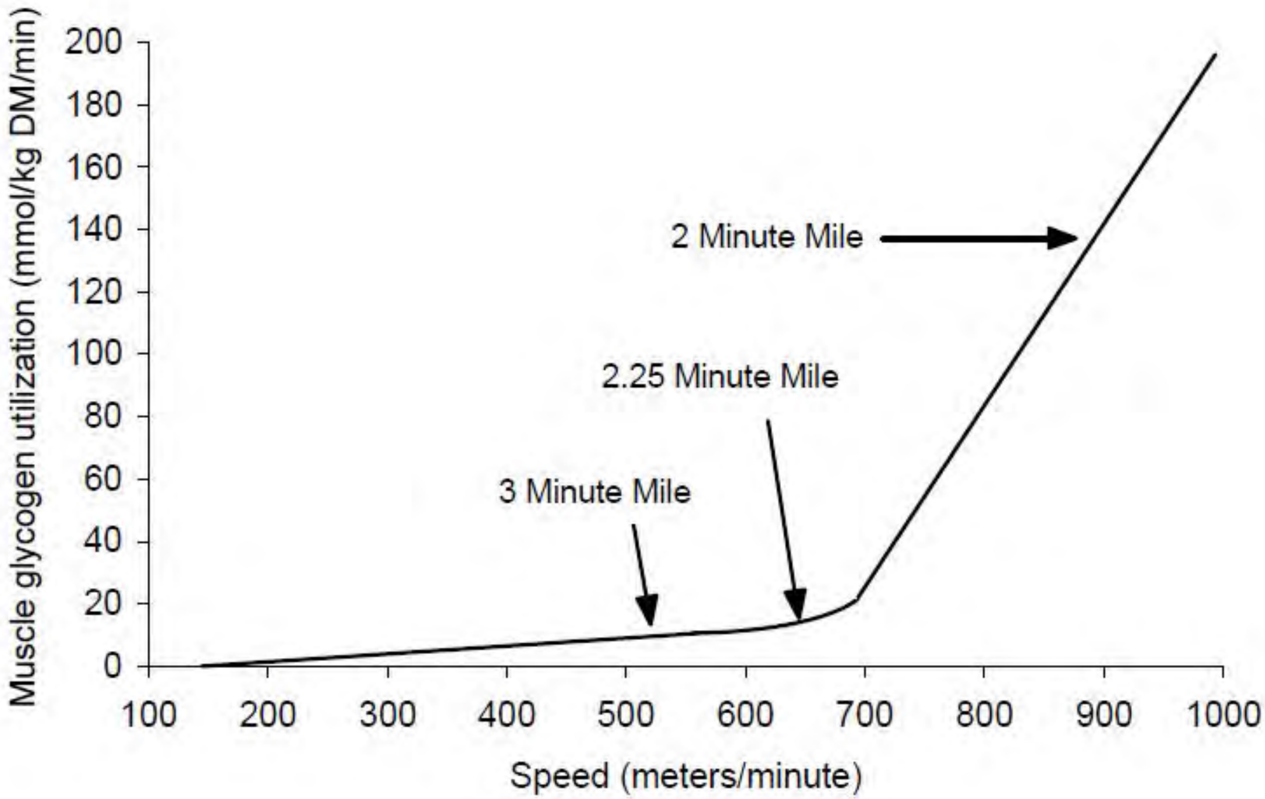
Horse muscle uses glycogen as its preferred fuel during strenuous exercise



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Effect of non-structural carbohydrate, fat and fiber intake on glycogen repletion following intense exercise

[1]Mesquita VS, [2]Pagan JD, [3]Valberg SJ, [2]Waldridge BM, [2]Whitehouse C.

[1]Universidade Estadual Paulista, Jaboticabal, São Paulo, Brazil; [2]Kentucky Equine Research, Versailles, KY, United States; [3] Michigan State Univ., East Lansing, MI, United States.

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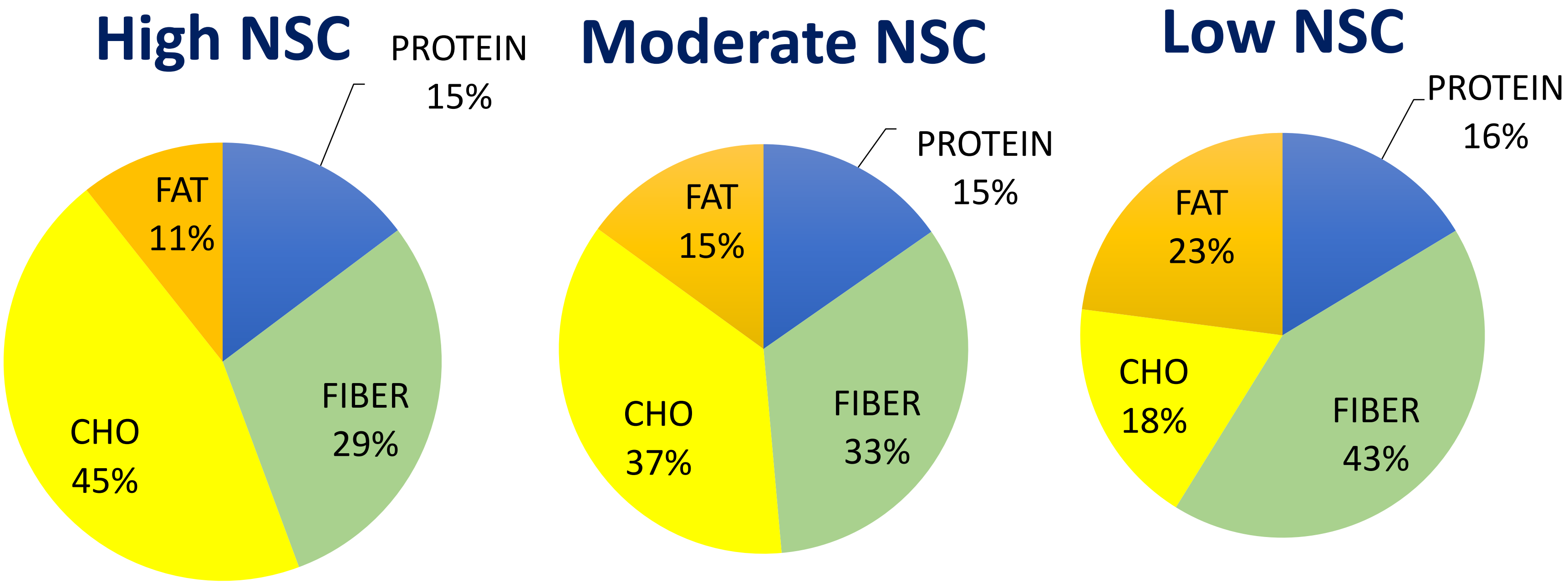
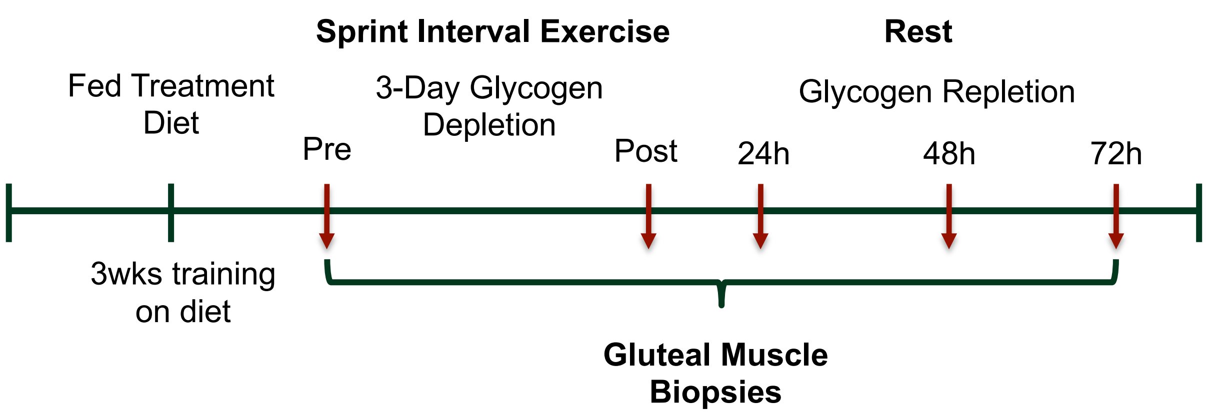
DIGESTIBLE ENERGY CONTRIBUTION (% OF TOTAL DE)

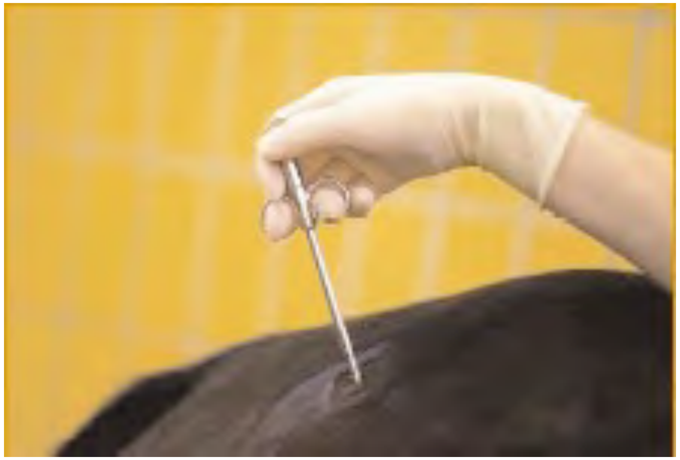


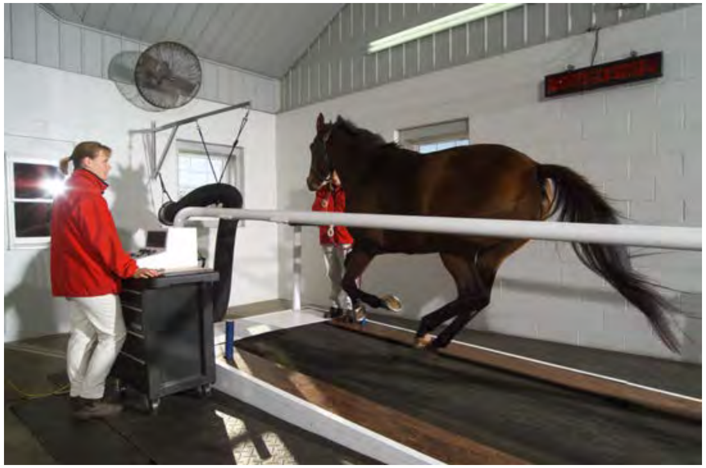
Materials and Methods: Glycogen Depletion

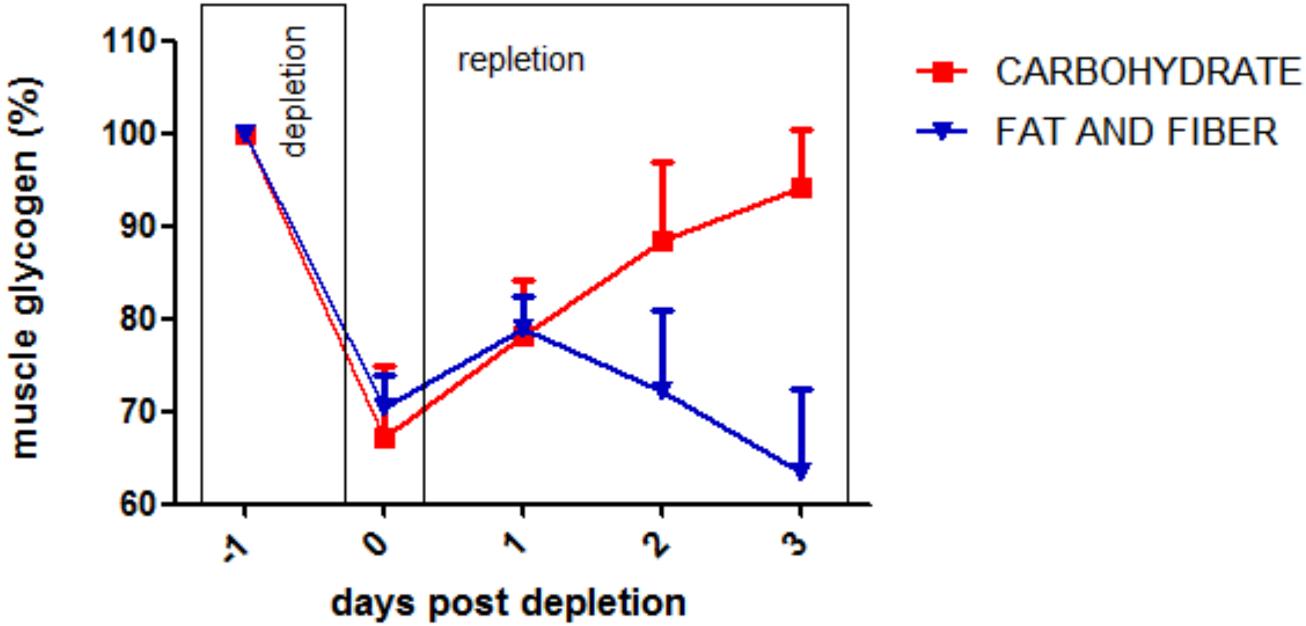
- 3 days of intense treadmill exercise 3° slope
  1. Incremental maximal exercise test
  2. Interval workout
  3. Interval work out



Equine Veterinary Journal 46, Suppl. 46 (2014 2-55)







muscle glycogen (%)
110
100
90
80
70
60
depletion
repletion
-1
0
1
2
3
days post depletion
CARBOHYDRATE
FAT AND FIBER

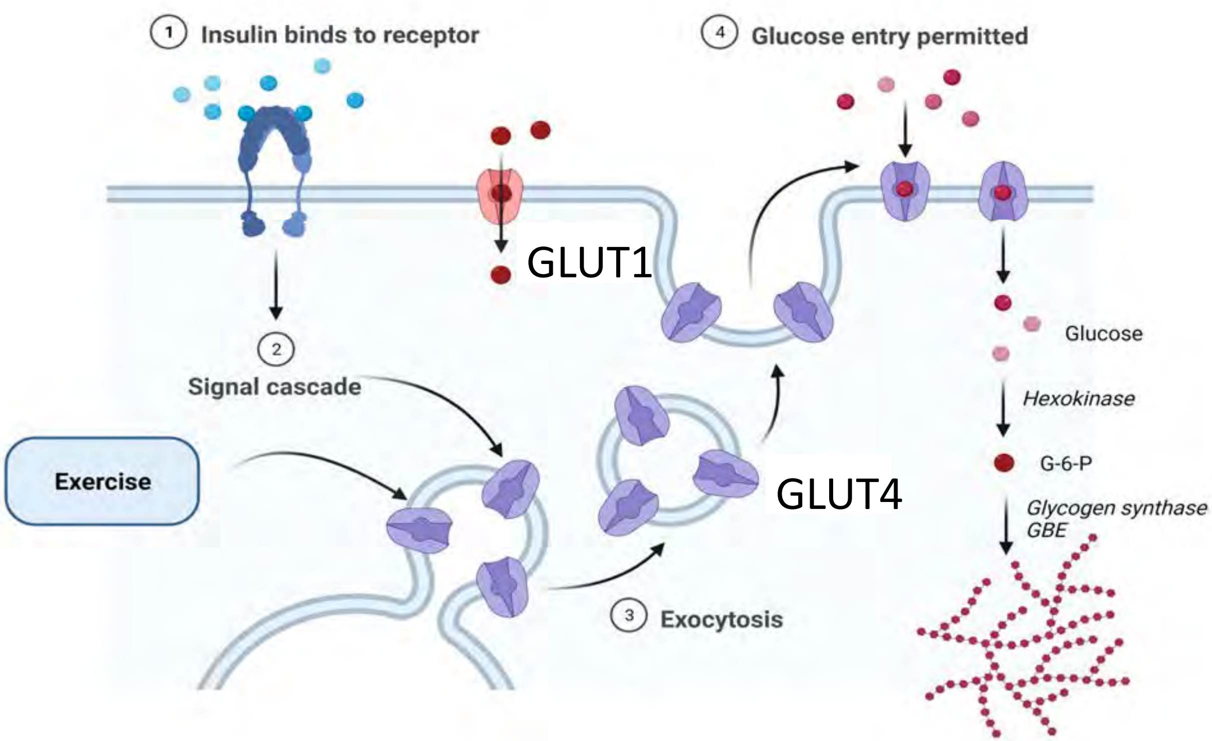
Transcriptomic analysis of pathways limiting glycogen repletion in the horse

Deborah Vélez-Irizarry[1], J Pagan[2], V Mesquita[2], SJ Valberg[1]
[1]McPhail Equine Performance Center,
Department of Large Animal Clinical Sciences
Michigan State University
[2] Kentucky Equine Research, Versailles KY

Glucose Transport

Glycogen synthesis

- Rate limiting step - glucose transport into muscle cell



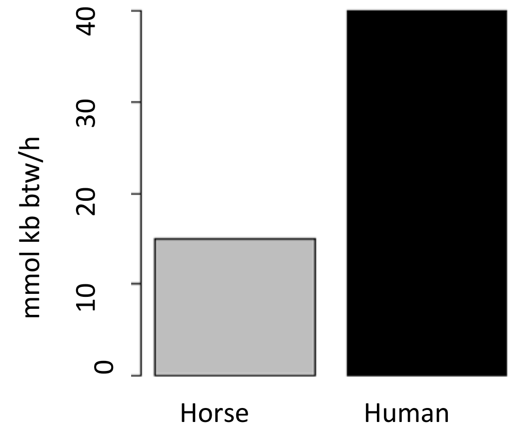
Glucose transport

Physiological *in vitro* insulin stimulation

- Humans: 80% ↑GLUT4 translocation
- Horses: 15% ↑GLUT4 translocation

Lacombe et al Int Schol Res Articles 2014

Glycogen Resynthesis Rate 4h Post Exercise with CHO Administration



Waller et al Equine vet. J. (2010) 42 (3):274-281

Glucose transporters

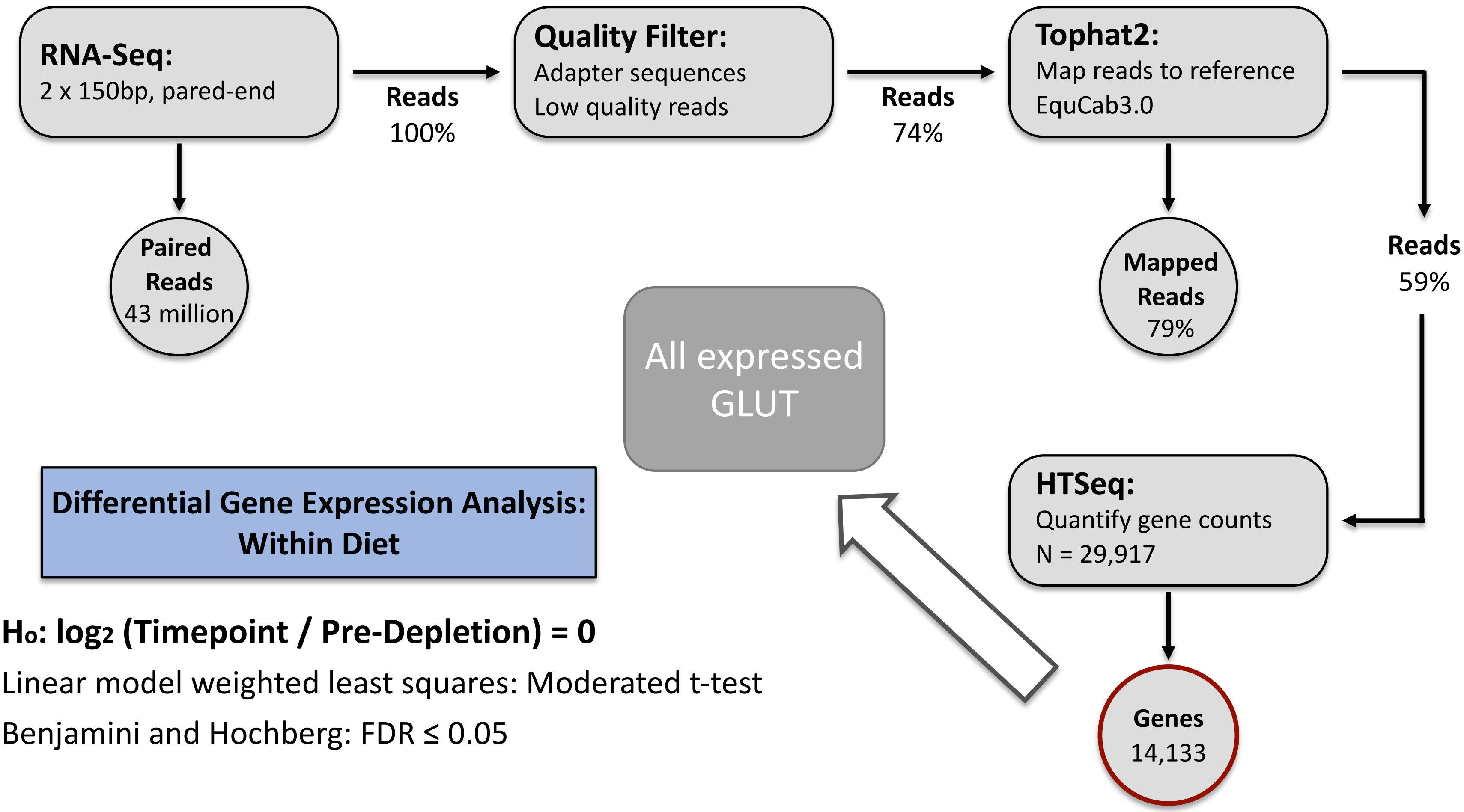
Aerobic exercise

- **GLUT1**
- GLUT3
- **GLUT4**
- GLUT5
- GLUT6
- GLUT8
- GLUT10
- GLUT11
- **GLUT12**

Resistance training

- **GLUT1**
- **GLUT3**
- GLUT4
- GLUT5
- **GLUT6**
- GLUT8
- **GLUT10**
- GLUT11
- GLUT12

Methods: Quantify Gene Expression



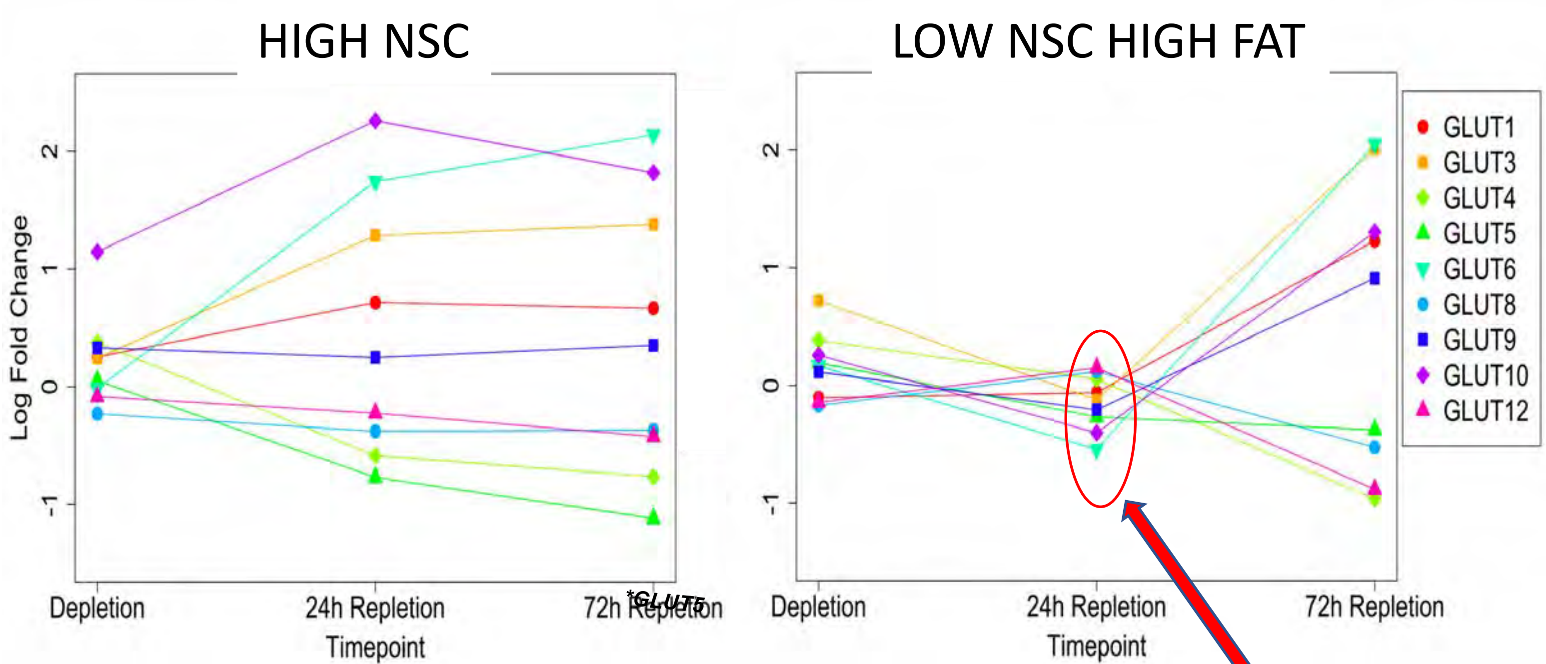
Differential Gene Expression Analysis: Within Diet

H_0: log_2 (Timepoint / Pre-Depletion) = 0

Linear model weighted least squares: Moderated t-test

Benjamini and Hochberg: FDR ≤ 0.05

Glucose Transporter Gene Expression



Compared to pre-exercise

Low gene expression 24 hrs post depletion in high fat group

Conclusions

- Horses lack signaling mechanisms that activate GLUT4 transcription following glycogen depletion
- Lag in glycogen resynthesis on Low NSC-High Fat corresponds to lag in GLUT6 and GLUT10 expression
- Difficult to replete muscle glycogen without adequate carbohydrate in the diet

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FAT

Crude Fat (mostly triglycerides)

- Saturated Fatty Acids (SFA)
- Monounsaturated Fatty Acid (MUFA)
- Polyunsaturated Fatty Acids (PUFA)
  - -Omega-3 Total
  - -Omega-6 Total

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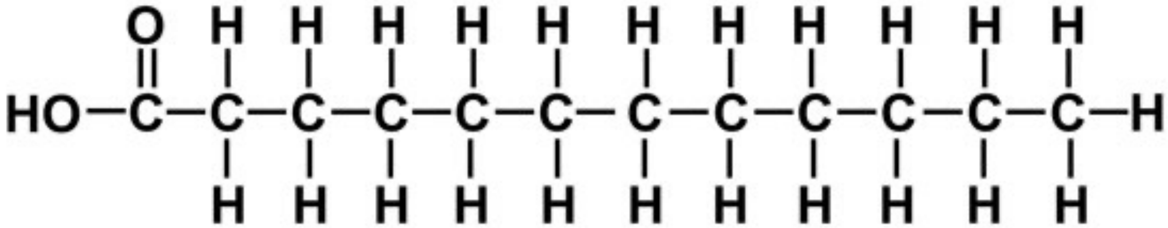
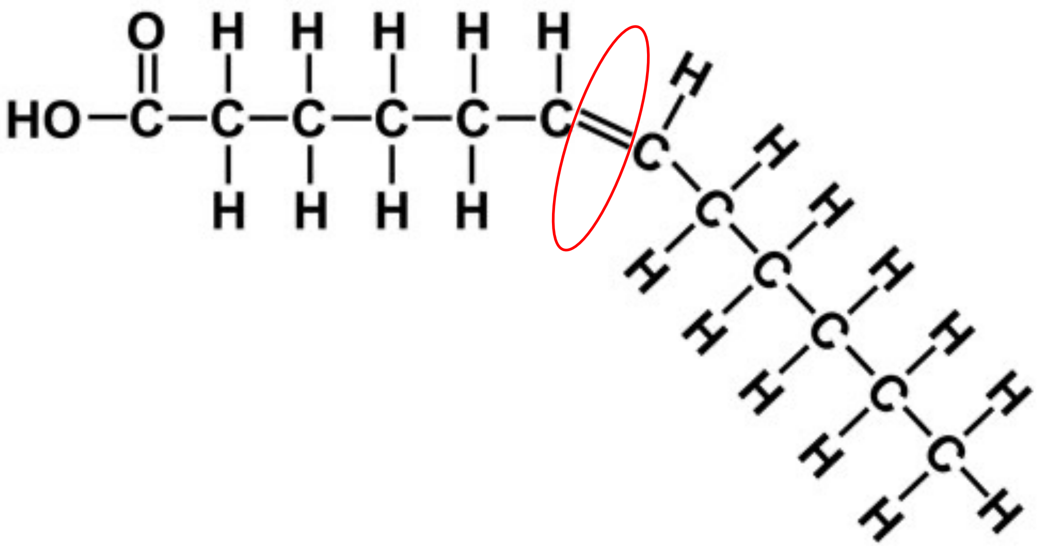
Saturated Fatty Acid



Unsaturated Fatty Acid



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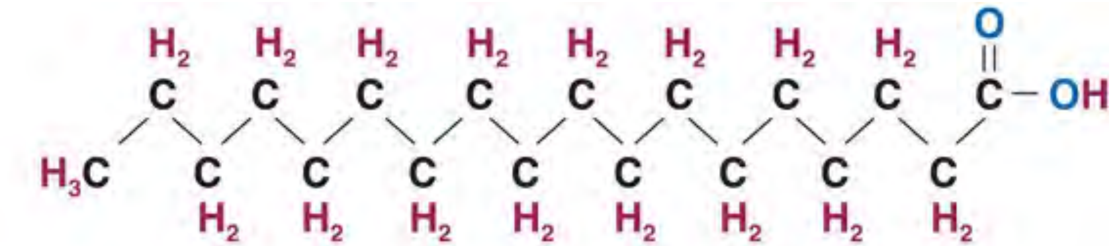
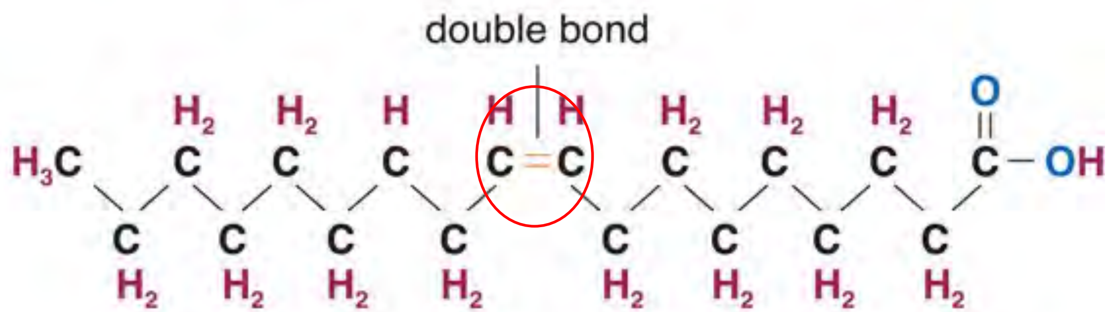
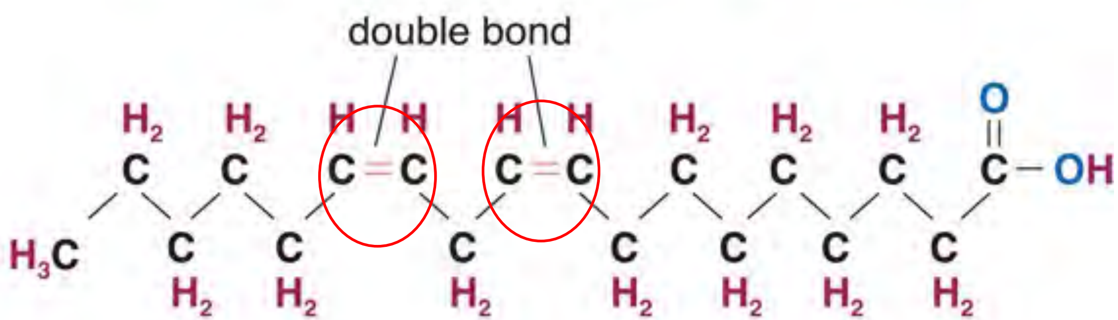
Stearic acid
$C_{18}H_{36}O_2$
A saturated fat



Oleic acid
$C_{18}H_{34}O_2$
A monounsaturated fat

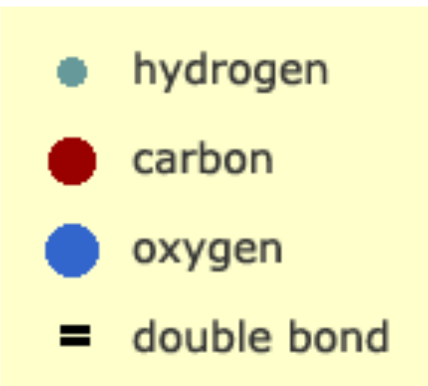


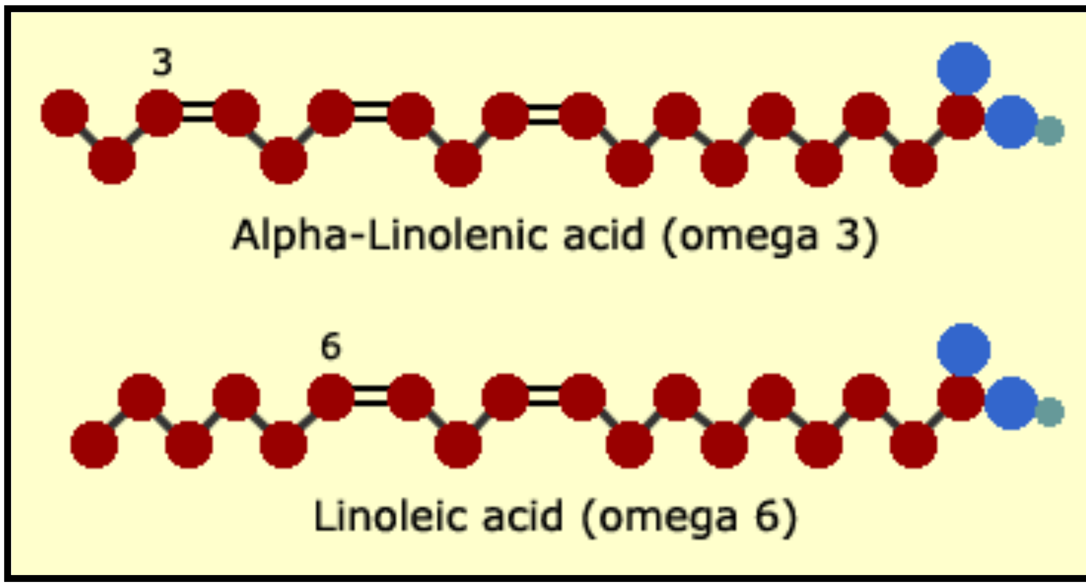
Linoleic acid
$C_{18}H_{32}O_2$
A polyunsaturated fat



Polyunsaturated fatty acids

Omega 3 and Omega 6





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Polyunsaturated Fatty Acids (PUFAs) can be further divided by chain length

- Short-chain polyunsaturated fatty acids (SC-PUFAs) have 18 or fewer carbon atoms
  - ALA, SDA and LA, GLA
- Long-chain polyunsaturated fatty acids (LC-PUFAs) have ≥20 carbons in their length
  - EPA, DHA and DGLA, AA

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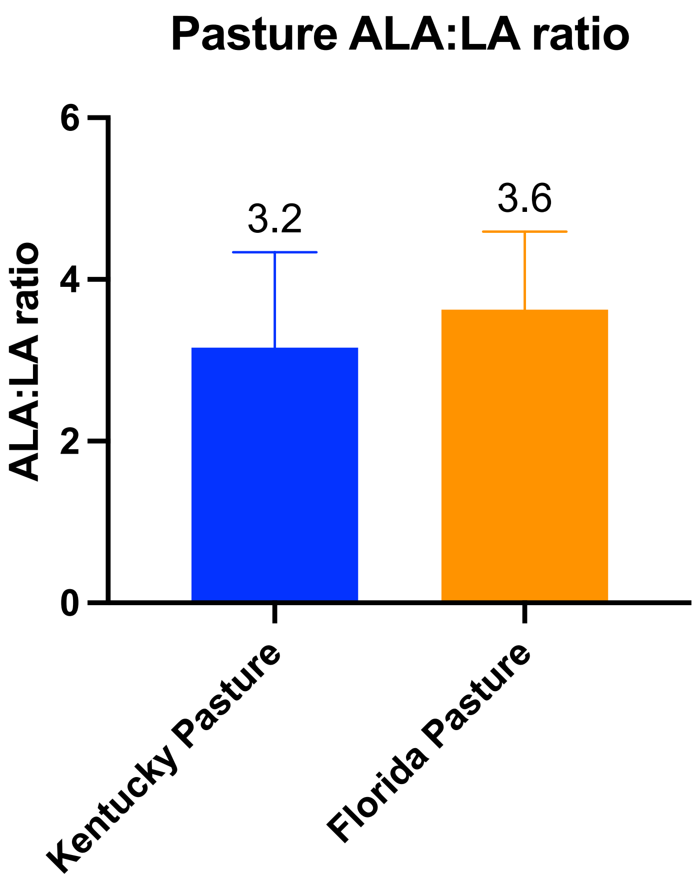
Omega 3:6 ratio in pasture



Pasture contains over **3 times more omega 3** than omega 6 fatty acids

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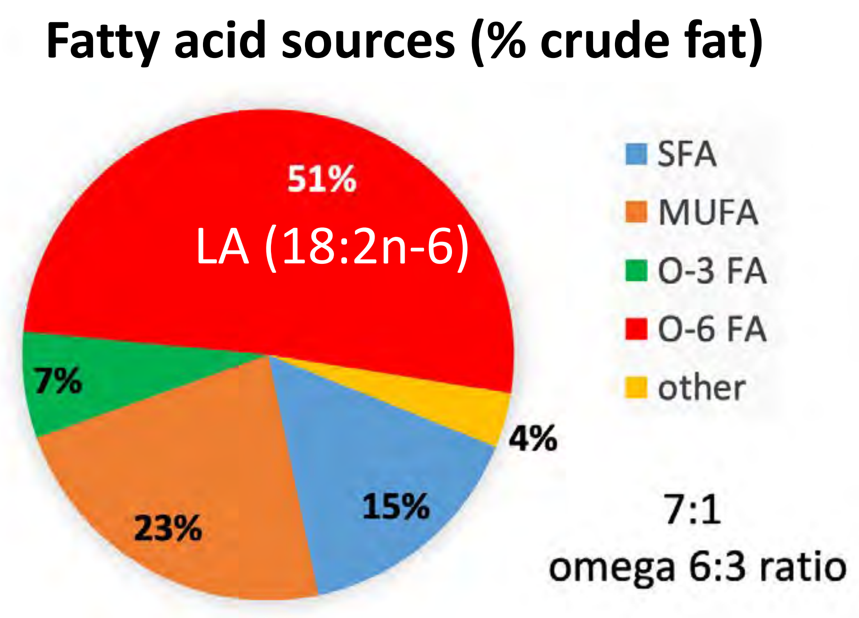
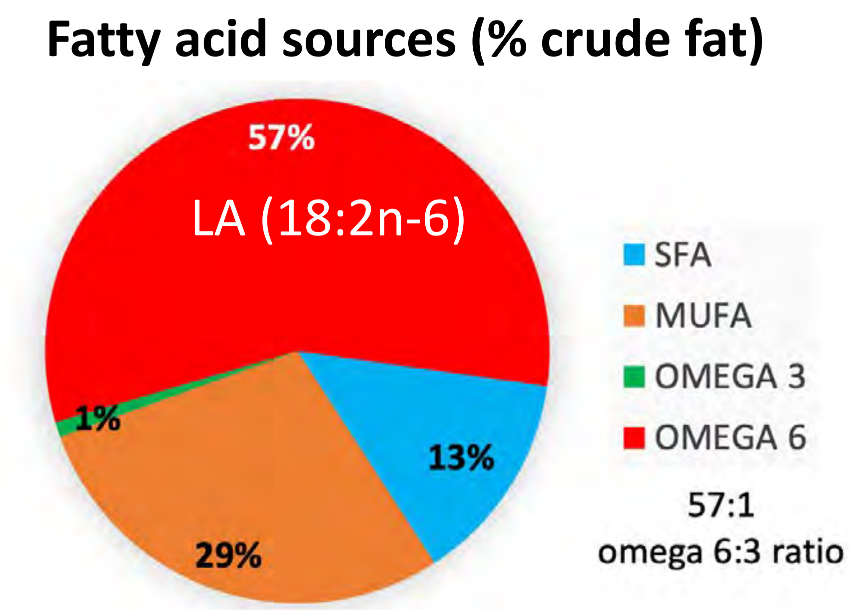
Soy Oil

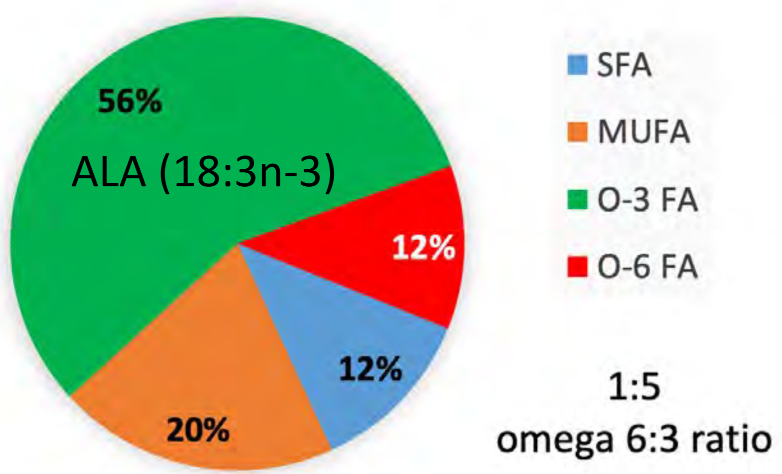


Corn Oil



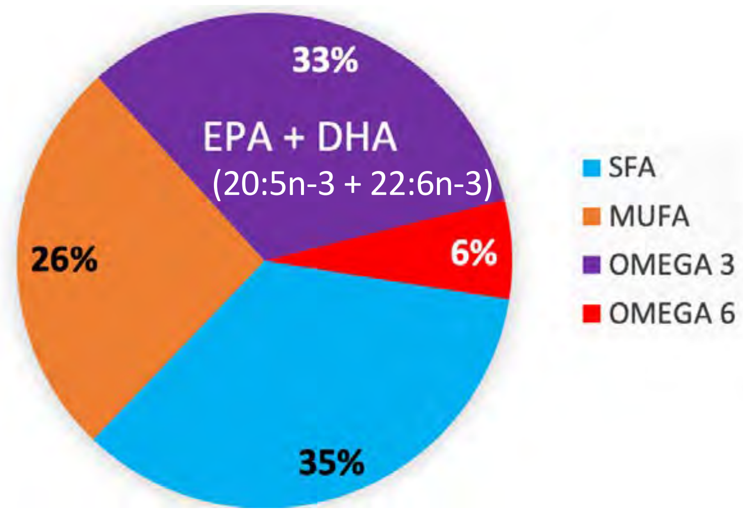
Flaxseed oil

Fatty acid sources (% crude fat)



Fish oil (EO-3)

Fatty acid sources (% crude fat)



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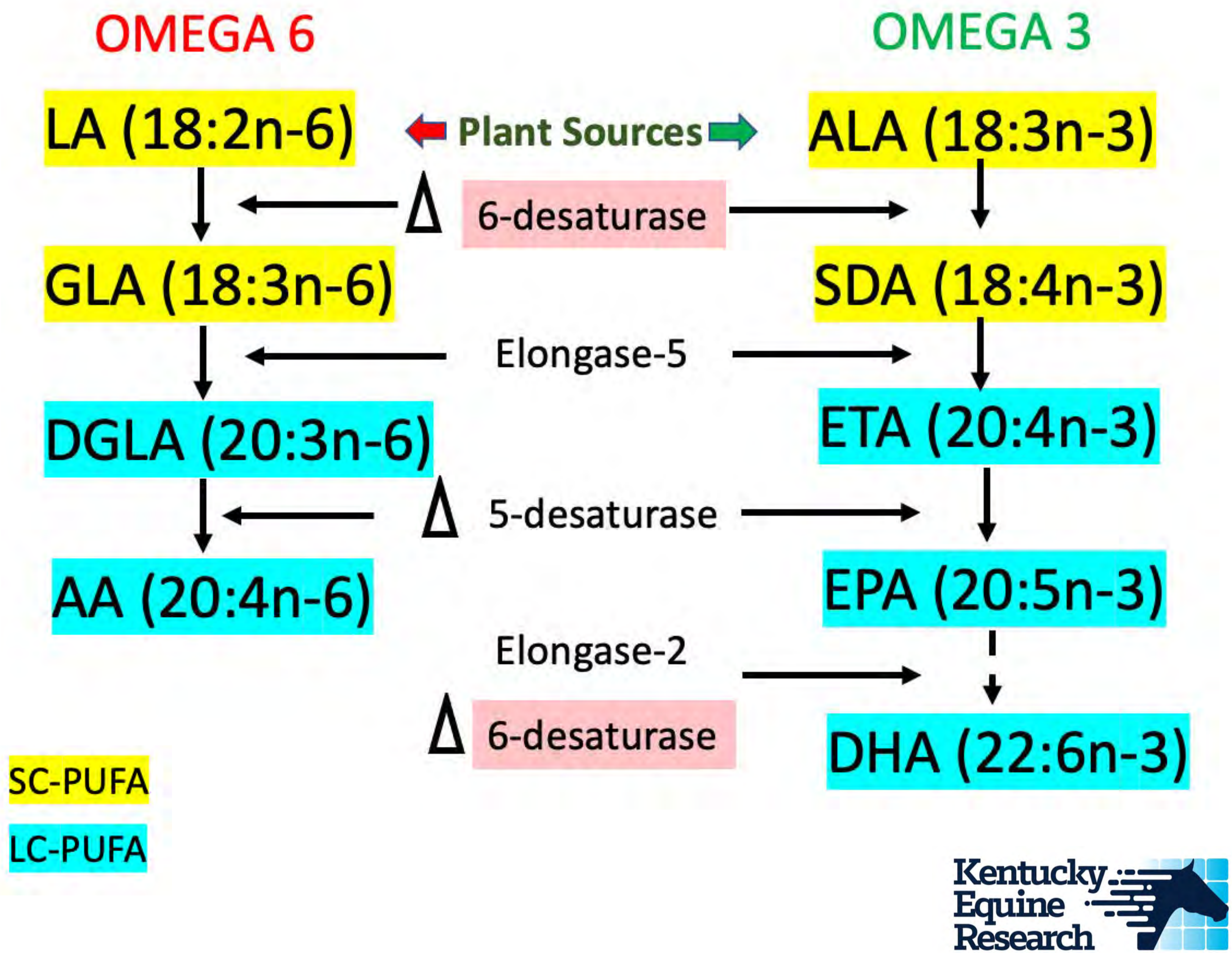

OMEGA 6
OMEGA 3
LA (18:2n-6)
Plant Sources
ALA (18:3n-3)
Δ 6-desaturase
GLA (18:3n-6)
SDA (18:4n-3)
Elongase-5
DGLA (20:3n-6)
ETA (20:4n-3)
Δ 5-desaturase
AA (20:4n-6)
EPA (20:5n-3)
Elongase-2
Δ 6-desaturase
DHA (22:6n-3)
SC-PUFA
LC-PUFA
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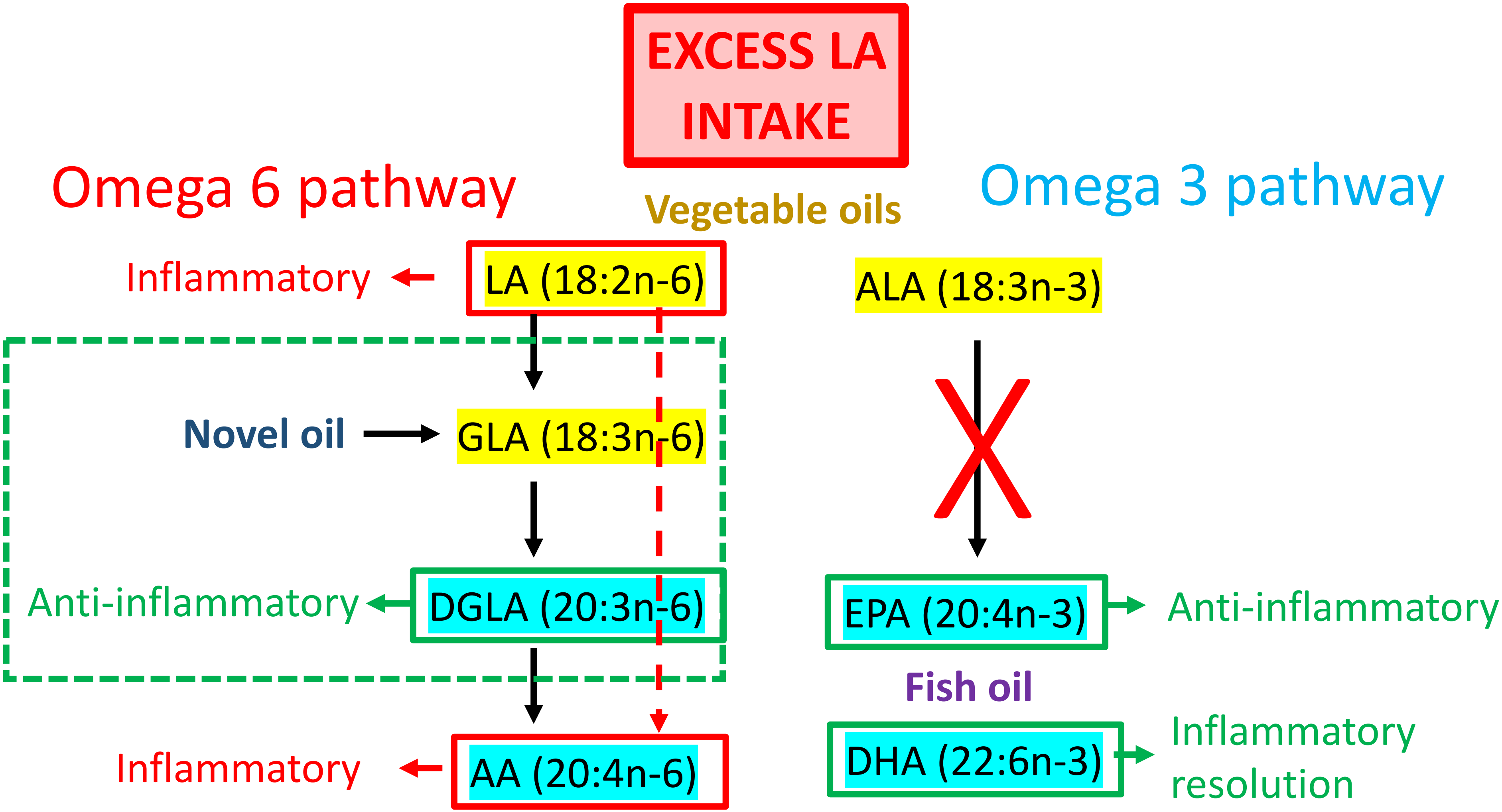

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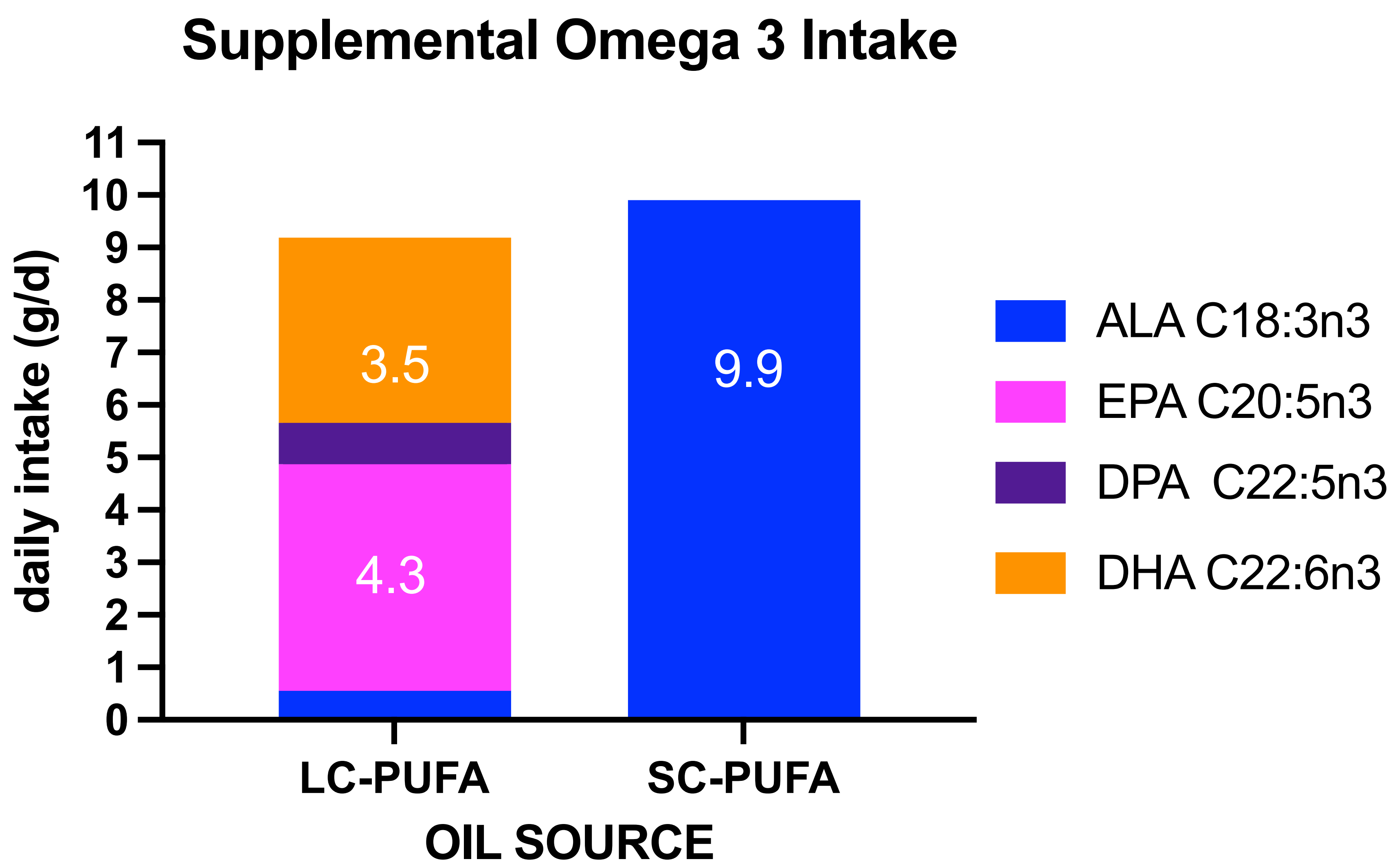
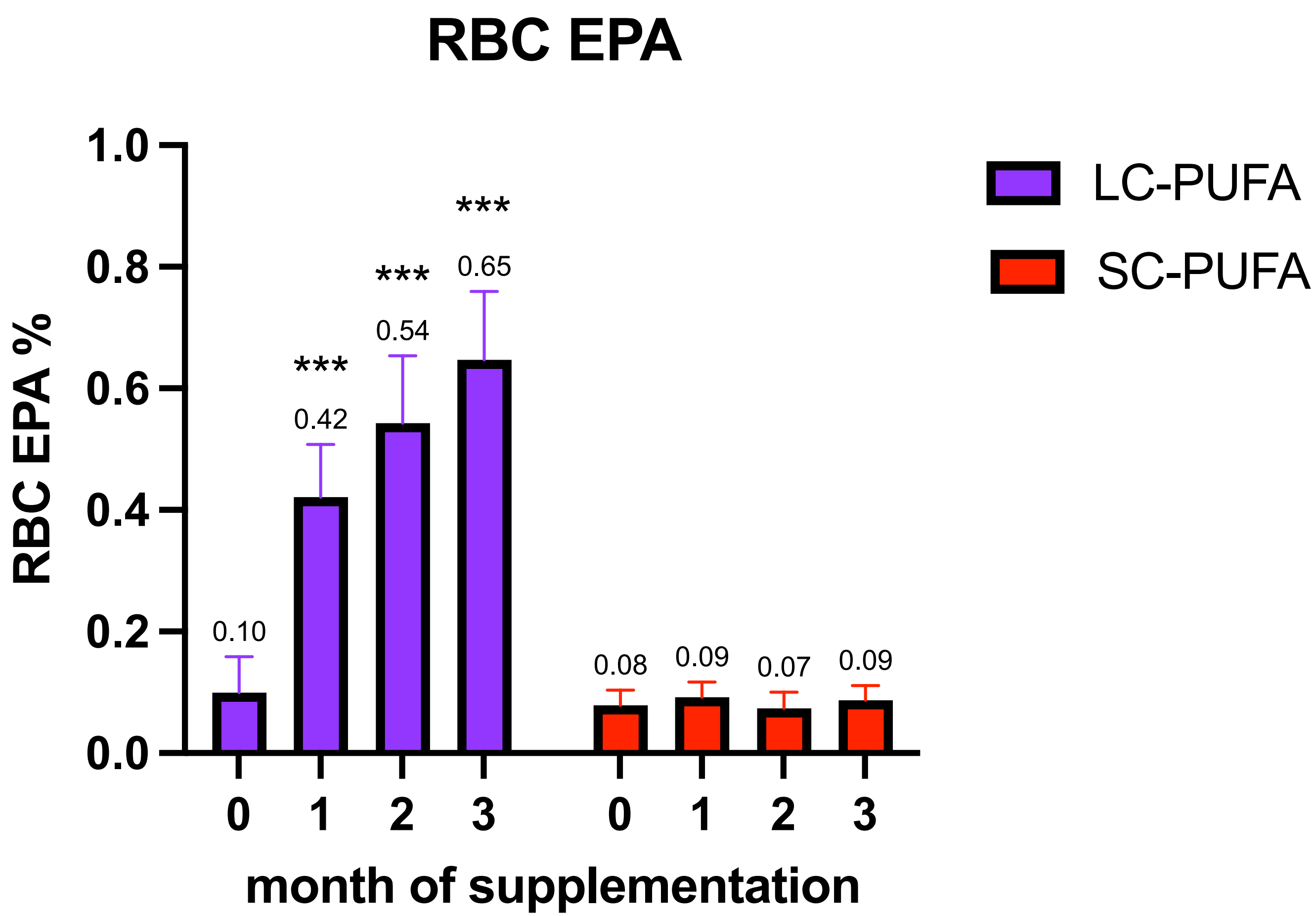
Kentucky Equine Research
Performance Center
Ocala Florida


13 Thoroughbreds
Three 90-day periods
• PRE supplementation period
• Two treatment periods
• LC-PUFA or SC-PUFA
• Switch-back design


Supplemental Omega 3 Intake
daily intake (g/d)
0
1
2
3
4
5
6
7
8
9
10
11
3.5
4.3
9.9
LC-PUFA
SC-PUFA
OIL SOURCE
ALA C18:3n3
EPA C20:5n3
DPA C22:5n3
DHA C22:6n3



*** different from month 0 (p<.001)

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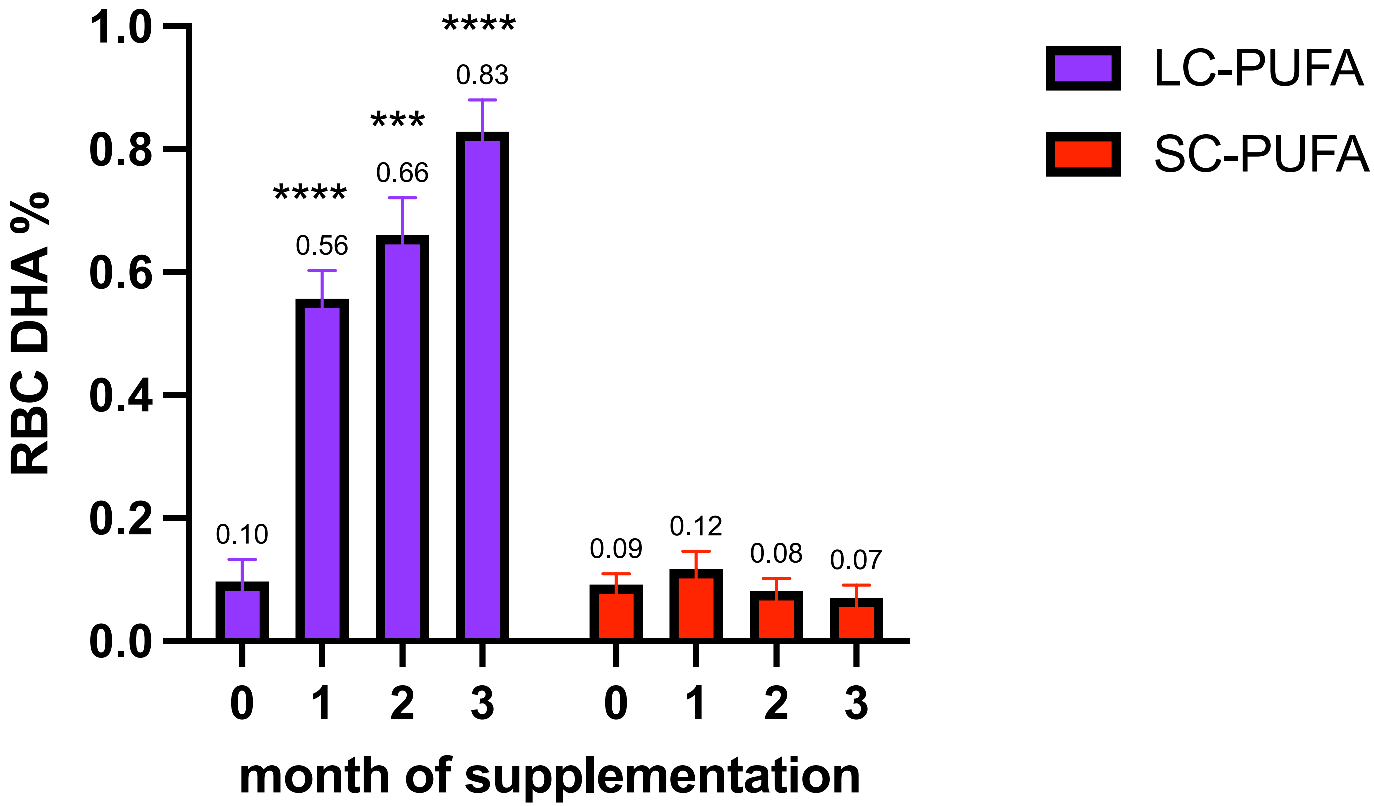
RBC DHA



*** different from month 0 ($p < .001$)

**** different from month 0 ($p < .0001$)

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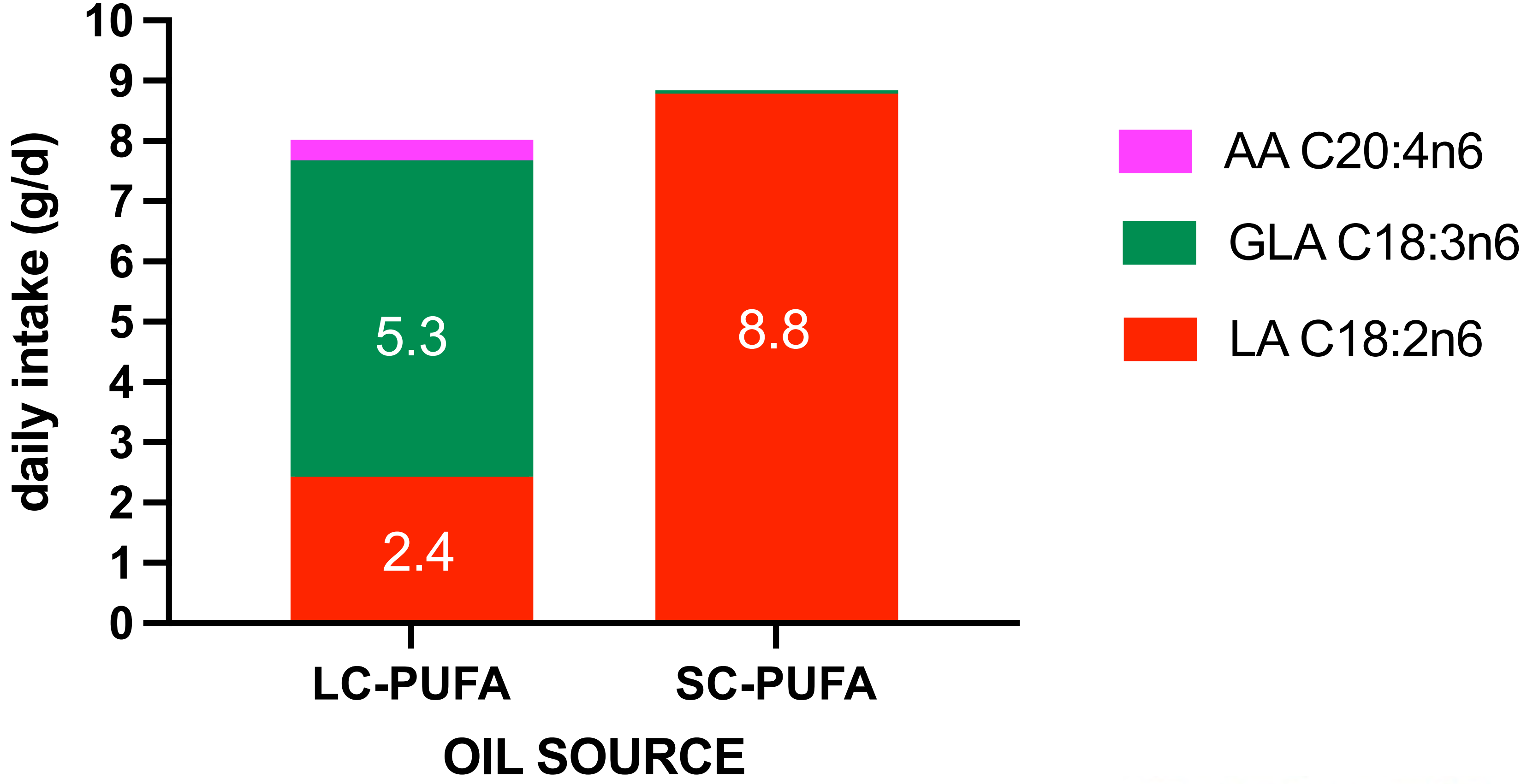
Supplemental Omega 6 Intake



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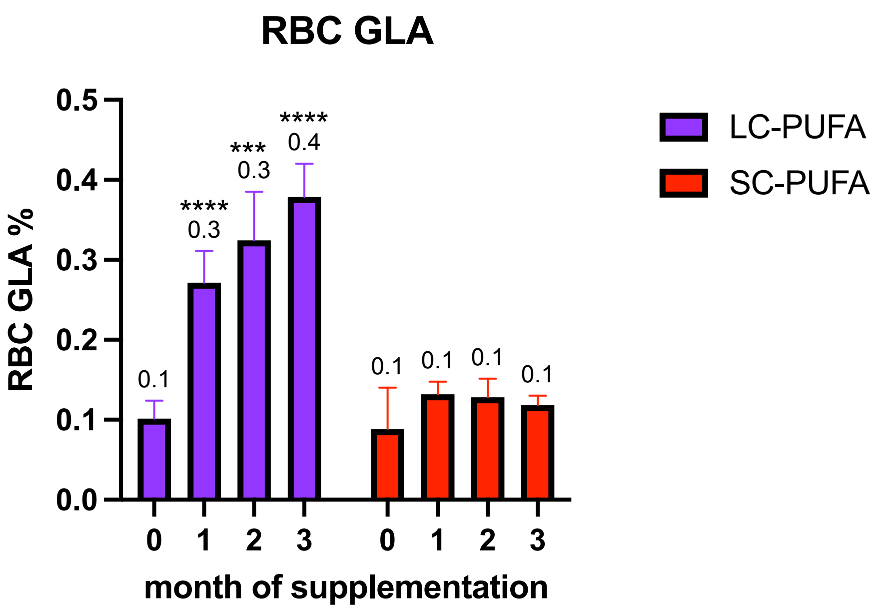
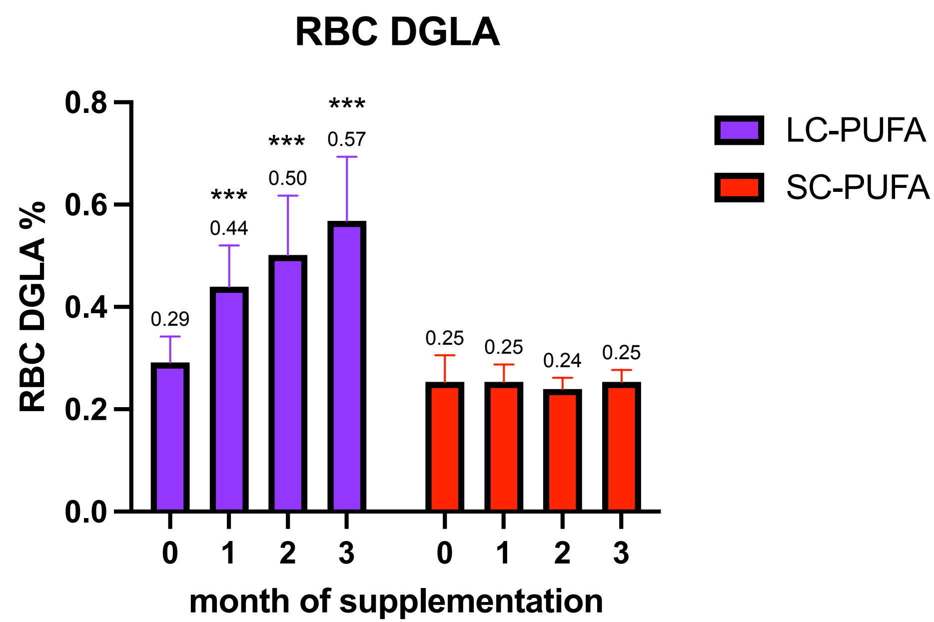
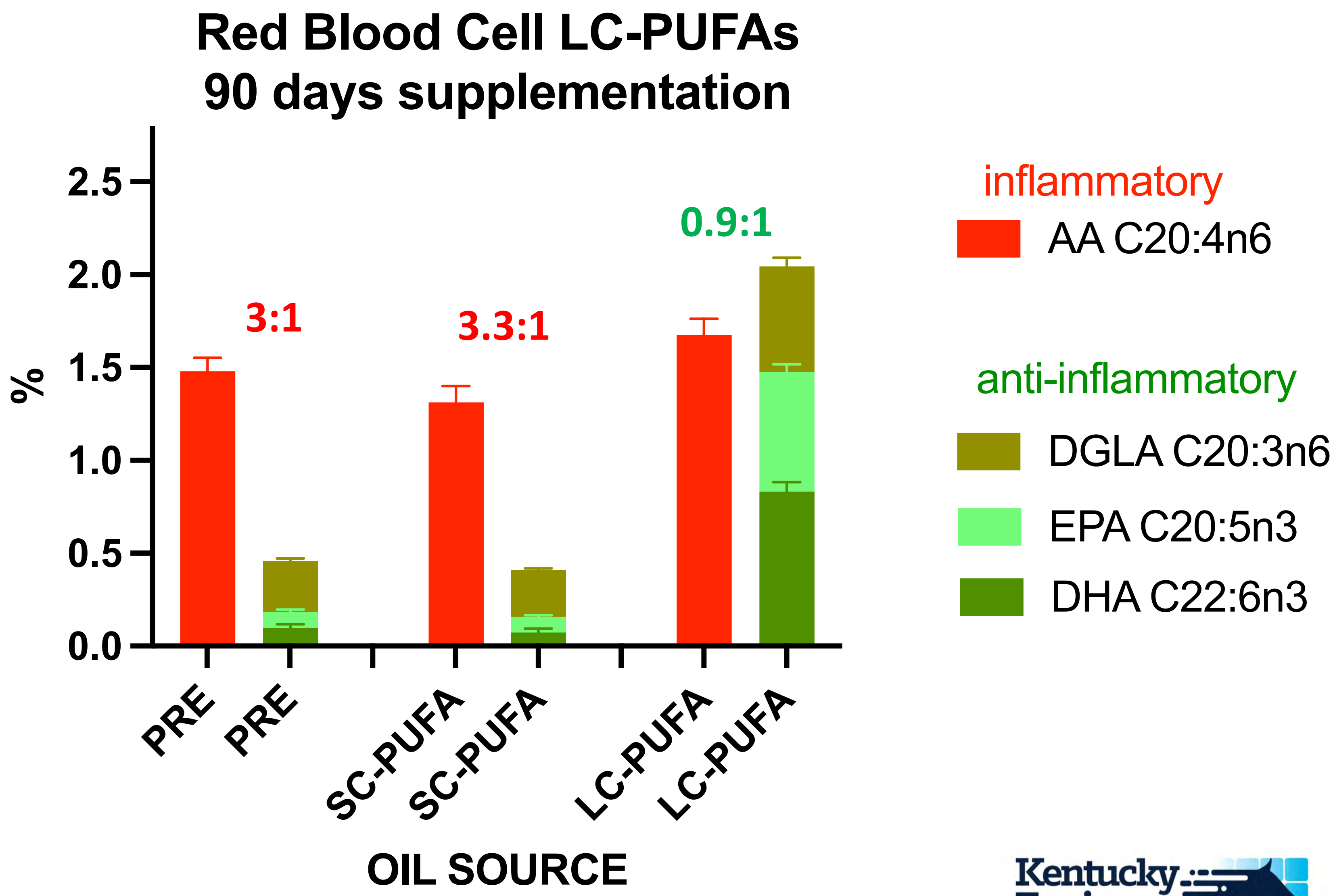


*** different from month 0 (p<.001)
****different from month 0 (p<.0001)



*** different from month 0 (p<.001)


Red Blood Cell LC-PUFAs
90 days supplementation
%
2.5
2.0
1.5
1.0
0.5
0.0
3:1
3.3:1
0.9:1
PRE
PRE
SC-PUFA
SC-PUFA
LC-PUFA
LC-PUFA
OIL SOURCE
inflammatory
AA C20:4n6
anti-inflammatory
DGLA C20:3n6
EPA C20:5n3
DHA C22:6n3
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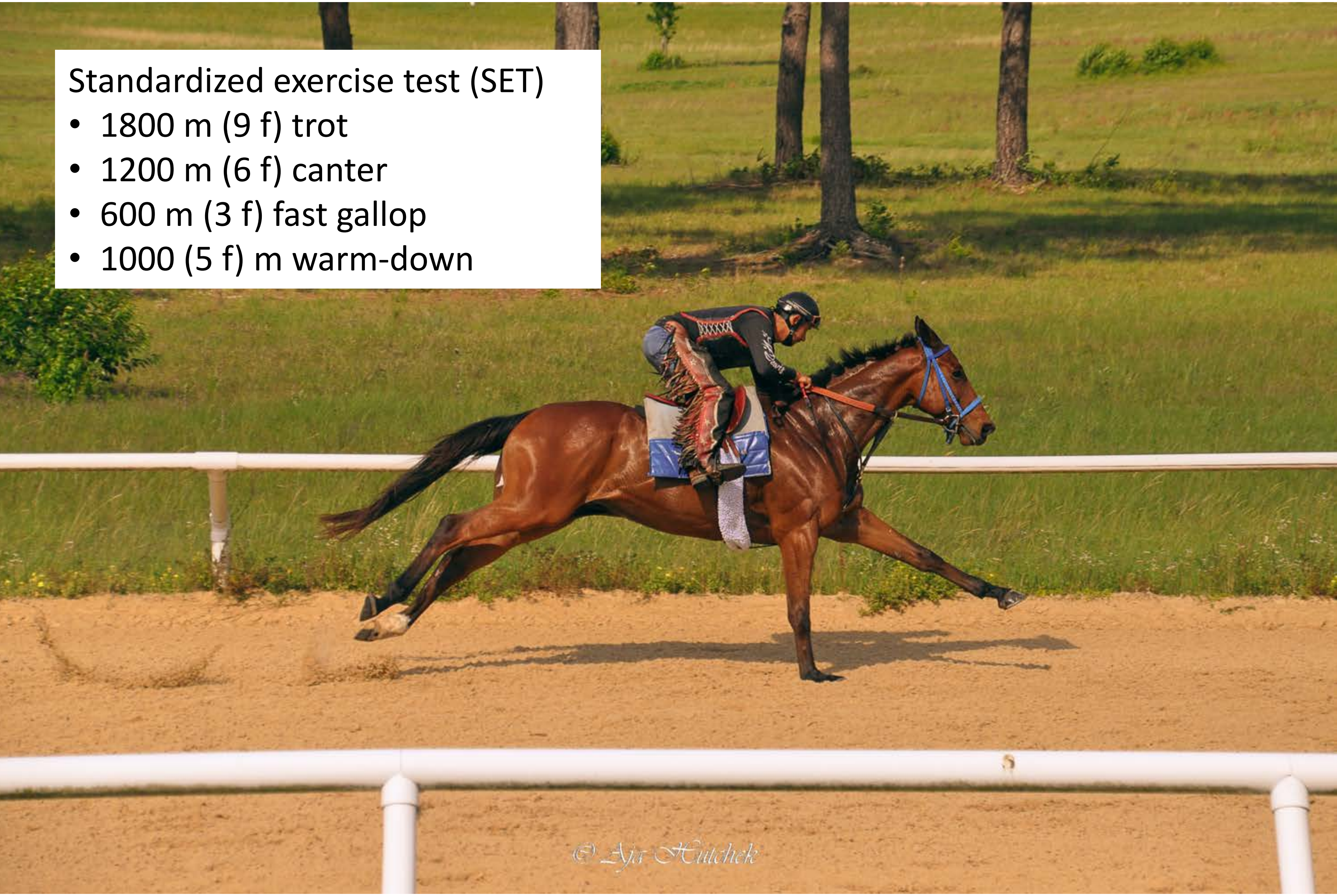
Standardized exercise test (SET)

- 1800 m (9 f) trot
- 1200 m (6 f) canter
- 600 m (3 f) fast gallop
- 1000 (5 f) m warm-down



Response to strenuous exercise

LC-PUFA supplementation resulted in:

- ✓ Reduced heart rate during breeze
- ✓ Enhanced mitochondrial biogenesis
- ✓ Reduced red blood cells in lungs
- ✓ Reduced eosinophils in lungs
- ✓ Increased anti-inflammatory cytokines (IL-10)
- ✓ Decreased inflammatory cytokines (IL-8)
- ✓ Reduced gastric ulcers

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Conclusions

- LC-PUFA (DGLA-EPA-DHA) have beneficial effects on
  - Inflammation
    - Joints
    - Airways
  - EIPH
  - Gastric ulcers
- KER has developed a new unique source of LC-PUFA for horses

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Dietary Energy Sources

- **Plant Fiber**
- Non-structural carbohydrate (NSC)
  - Starch
  - Sugar
- Fat
- Protein

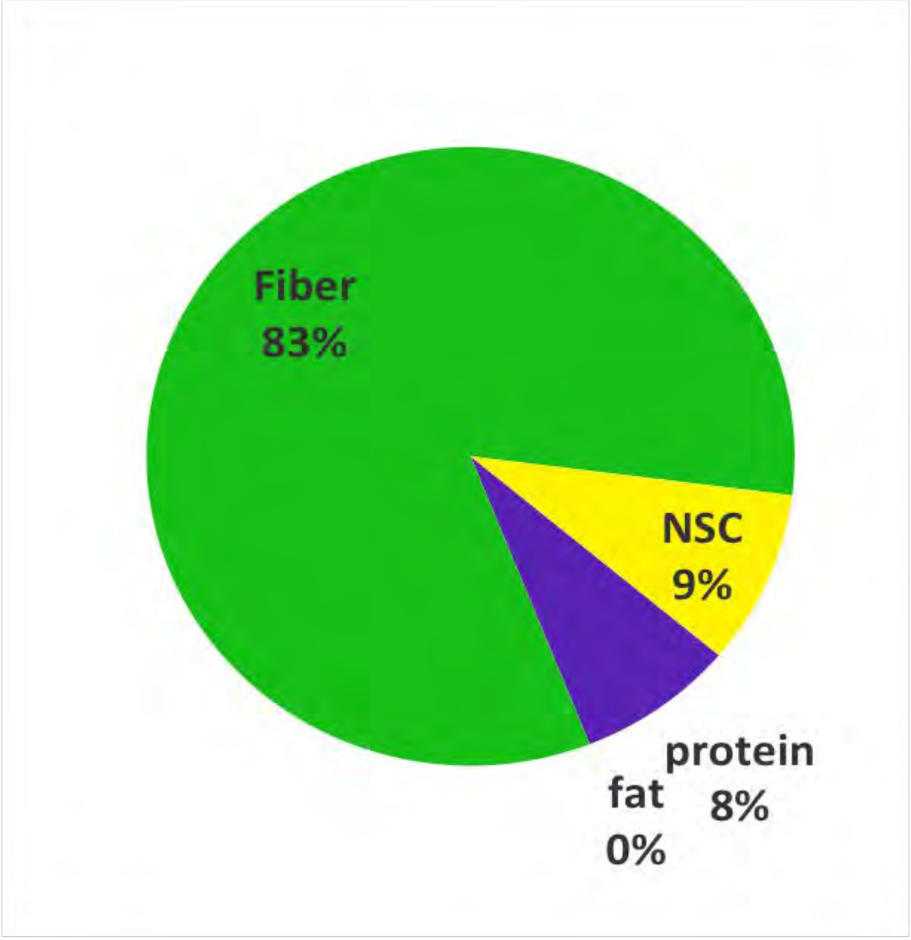
A comparison of grain, oil and **beet pulp** as energy sources for the exercised horse

KATHLEEN G. CRANDELL, **J. D. PAGAN**, PAT HARRIS, S. E. DUREN

Equine Veterinary Journal

Volume 31, Issue S30, pages 485–489, July 1999

Beet pulp as an energy source



Digestible Energy Distribution

Beet pulp contains "super fiber"

- Fiber is 75-80% digestible
- Digestible Energy almost as high as oats

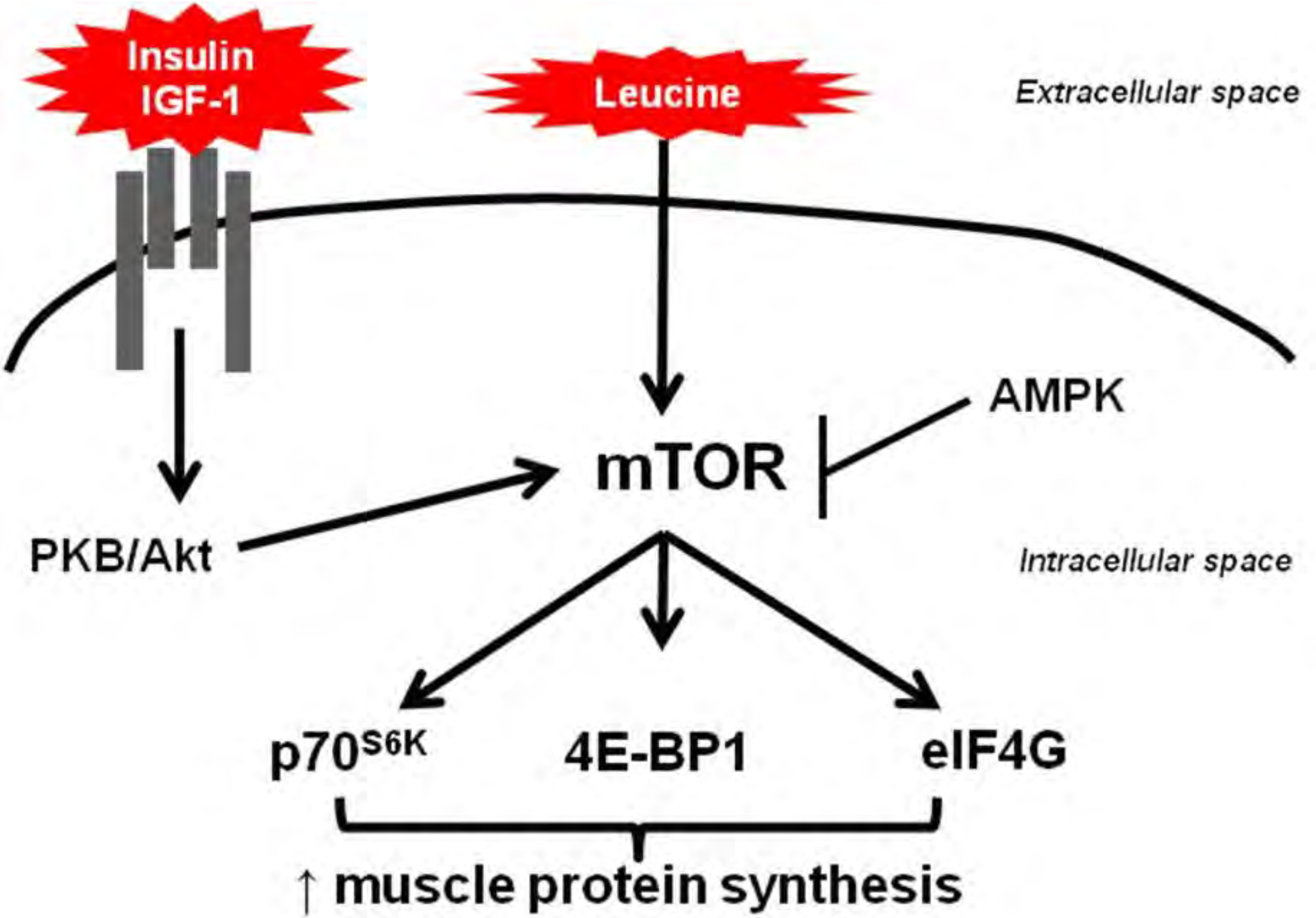
Dietary Energy Sources

- Plant Fiber
- Non-structural carbohydrate (NSC)
    - Starch
    - Sugar
- Fat
- **Protein**

Muscle Development

Skeletal muscle mass (**SMM**) =

Muscle protein synthesis (**MPS**) –
Muscle protein breakdown (**MPB**)


Insulin
IGF-1
Leucine
Extracellular space
AMPK
mTOR
PKB/Akt
Intracellular space
p70S6K
4E-BP1
eIF4G
↑ muscle protein synthesis

What form of energy should we supply in performance horse feeds?

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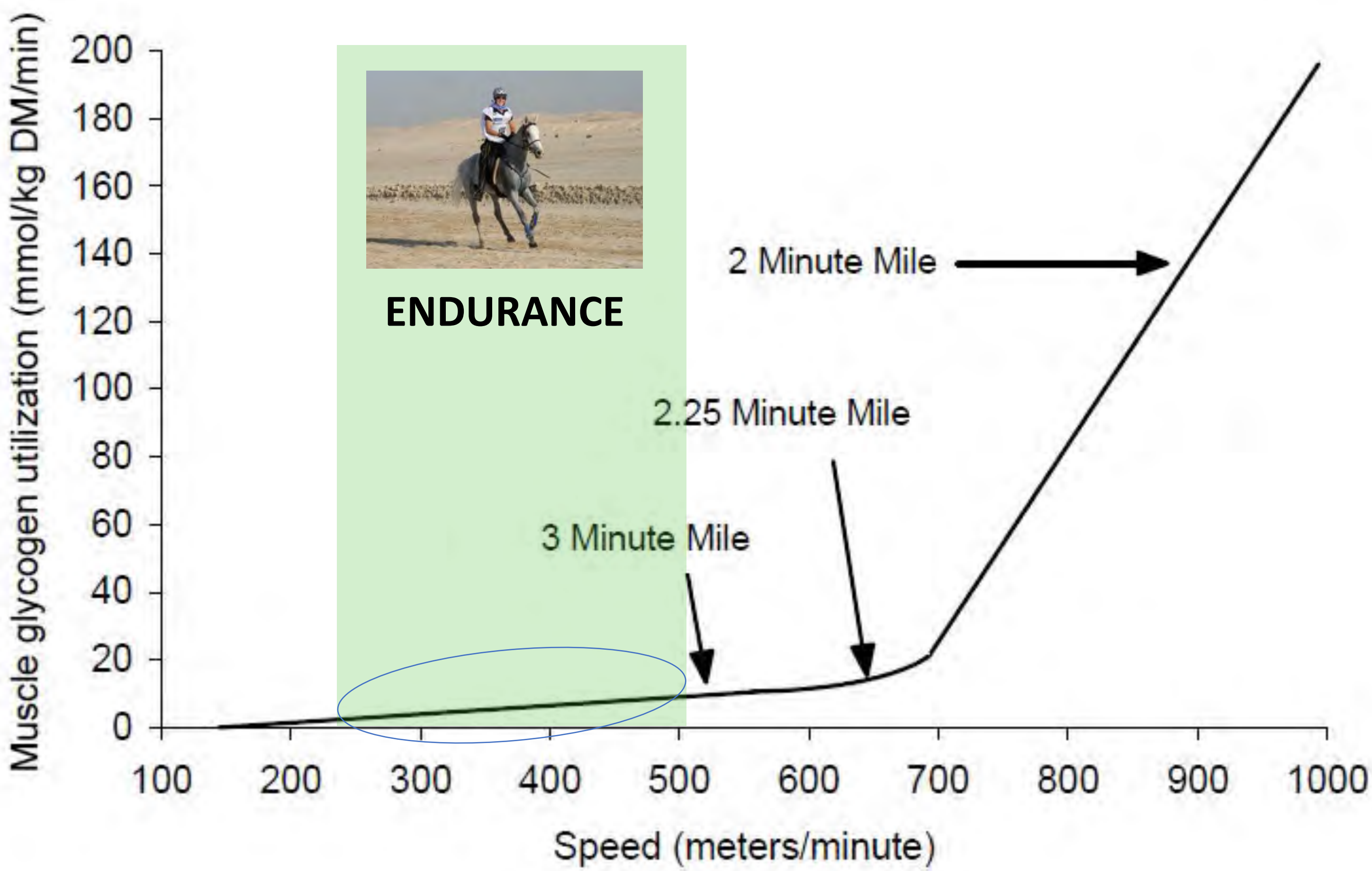
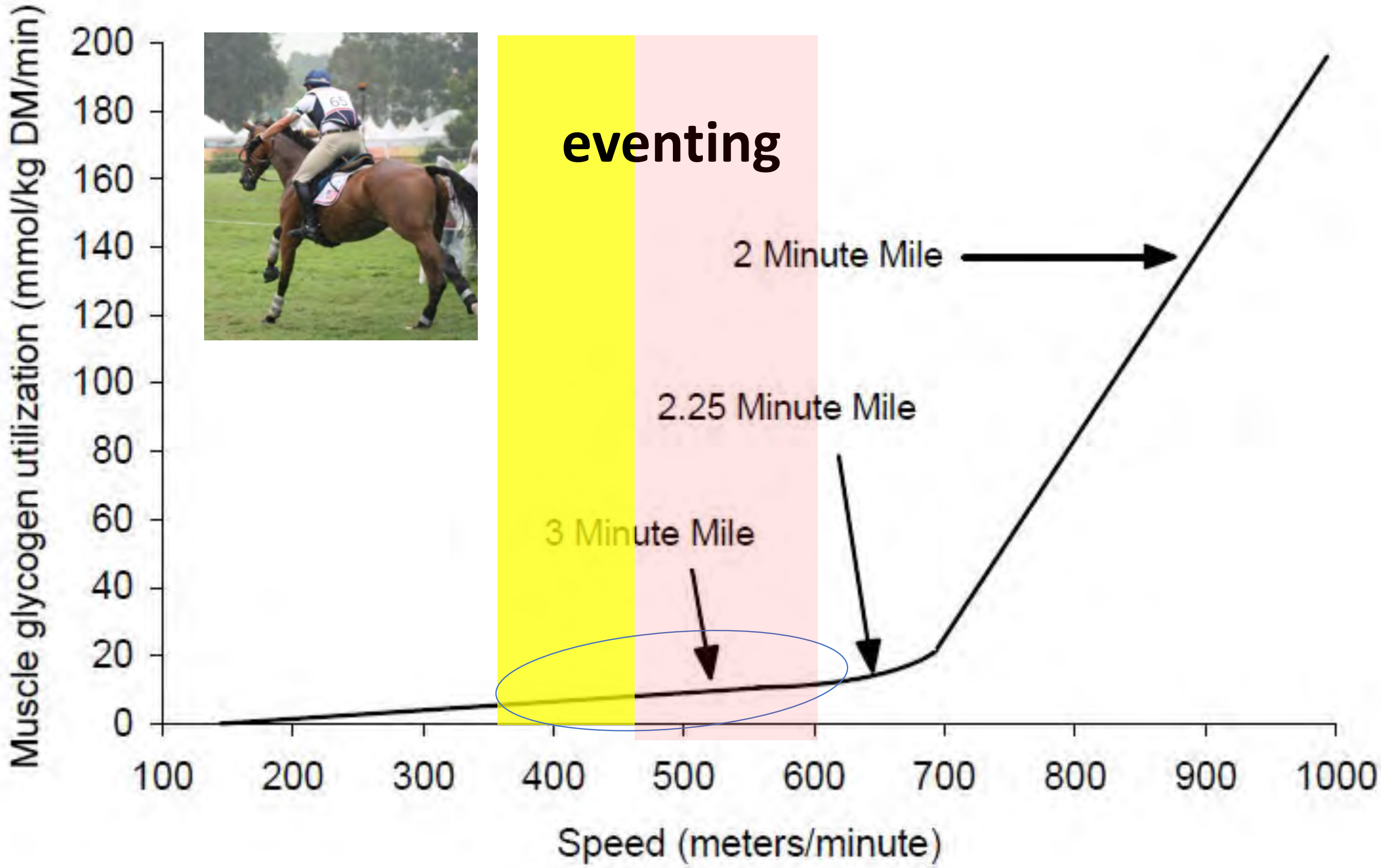
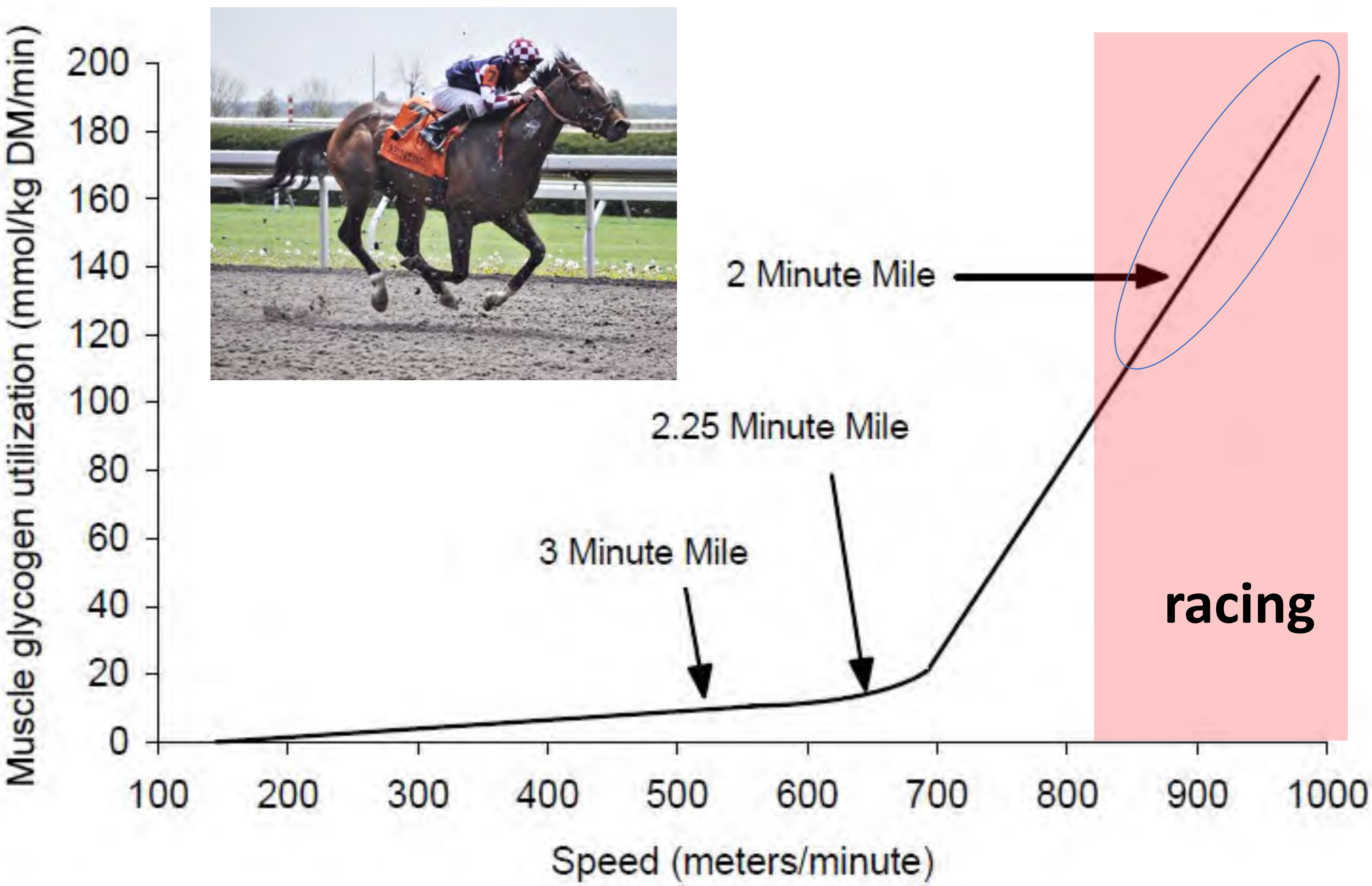
Muscle Glycogen Utilization as Function of Speed



Muscle Glycogen Utilization as Function of Speed



Muscle Glycogen Utilization as Function of Speed



Higher non-structural carbohydrate (NSC) diets needed for strenuous exercise (racing)

- Hindgut acidosis a concern
- Attenuate with
  - Grain processing
  - Smaller meal size
  - Encapsulated Buffers (EquiShure)
  - Pre, Pro, and Post biotics may also help (more research needed)

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Higher fat diets appropriate for lower intensity exercise (sport and endurance horses)

- Omega 6:3 PUFA imbalances an issue
  - Vegetable SC-PUFA (ALA) (flax oil) are not efficiently elongated to LC-PUFA
  - LC-PUFA supplementation needed to raise DGLA, EPA and DHA

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Highly fermentable fiber sources (super fibers) warranted for all performance horse feeds

- Beet pulp
- Soy hulls

Amount added depends on desired balance of energy sources in feed

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Quality protein important for performance horse feeds

- Stimulate muscle synthesis
  - *BCAA*
- Substrate for muscle synthesis
  - *Lysine*
  - *Methionine*
  - *Threonine*

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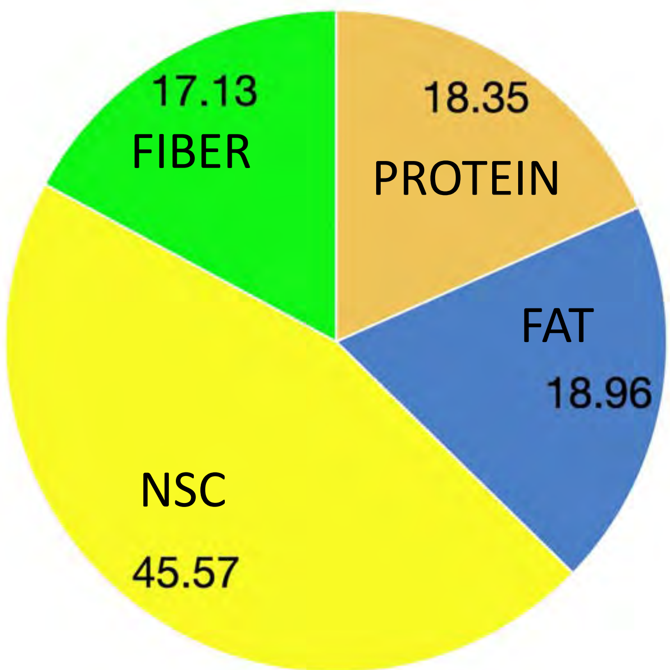
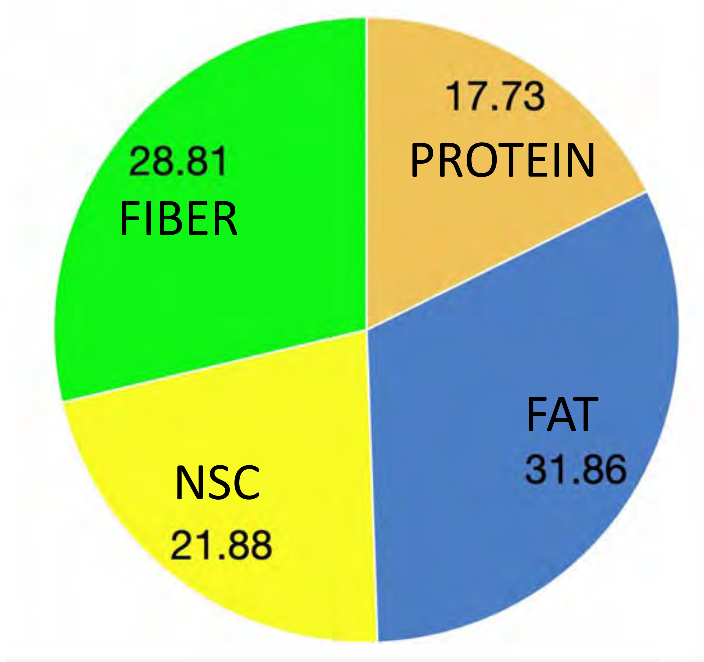
Energy Partitioning in Performance Feeds
% total Digestible Energy (DE)



Racing Feed



Sport Feed

Recent Developments in Performance Horse Health and Nutrition

Joe D. Pagan, Ph.D.

Kentucky Equine Research, Inc.

Kentucky Equine Research

World Leaders In Equine Nutrition