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Do pigs benefit from omega-3 fatty acids?

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Outline

Introduction

- What are omega-3 fatty acids?
- Why would we consider augmenting the diet of growing pigs, sows and piglets with omega-3 fatty acids

Experimental results

Conclusions

http://www.phytochemicals.info/plants/flaxseed.php

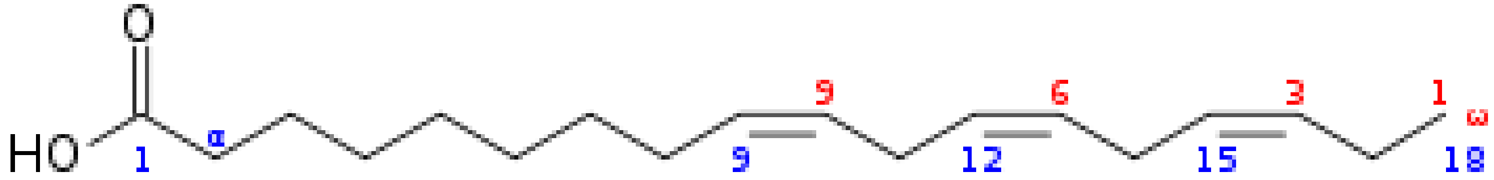
Omega-3 fatty acids

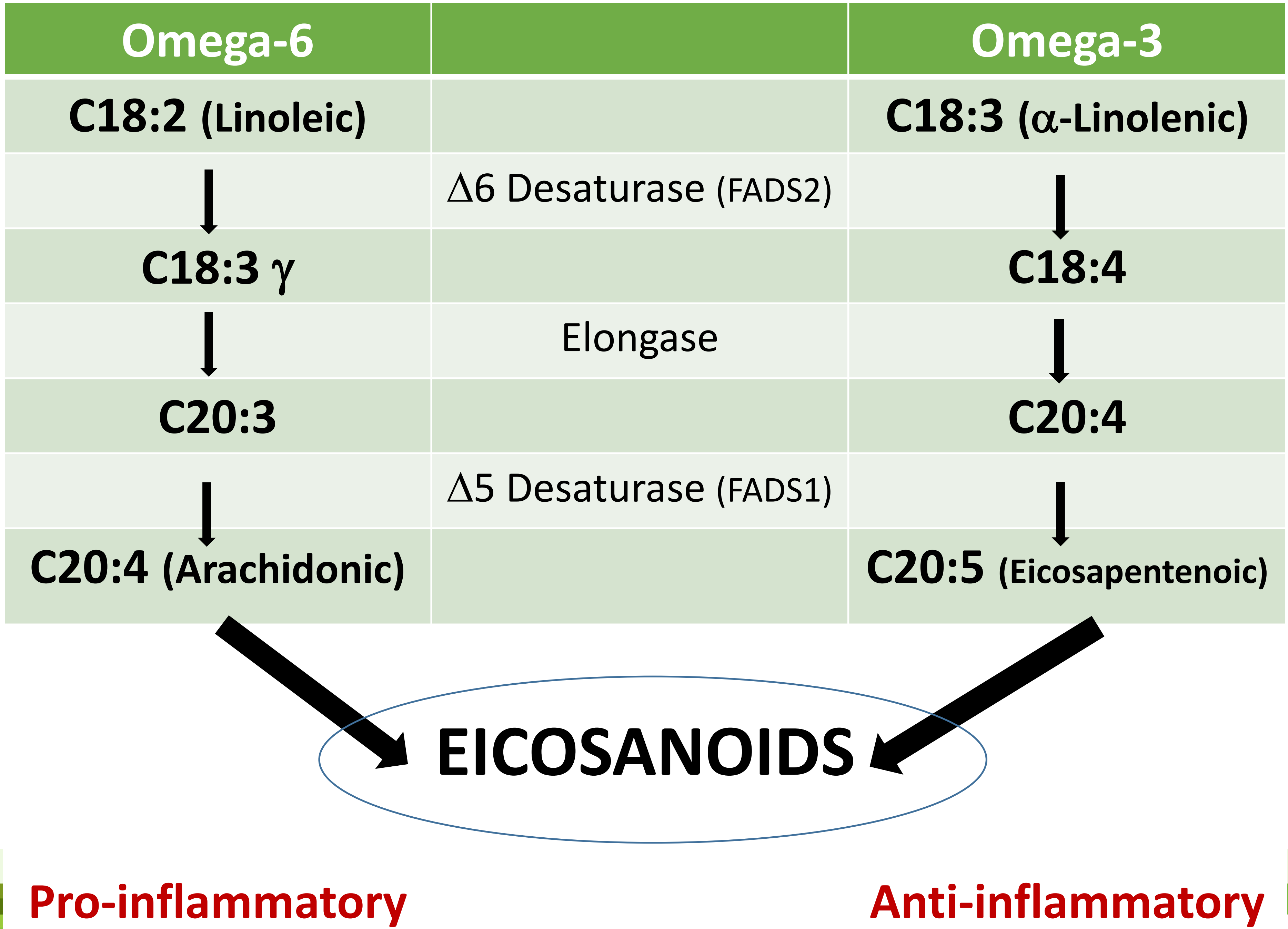
are:

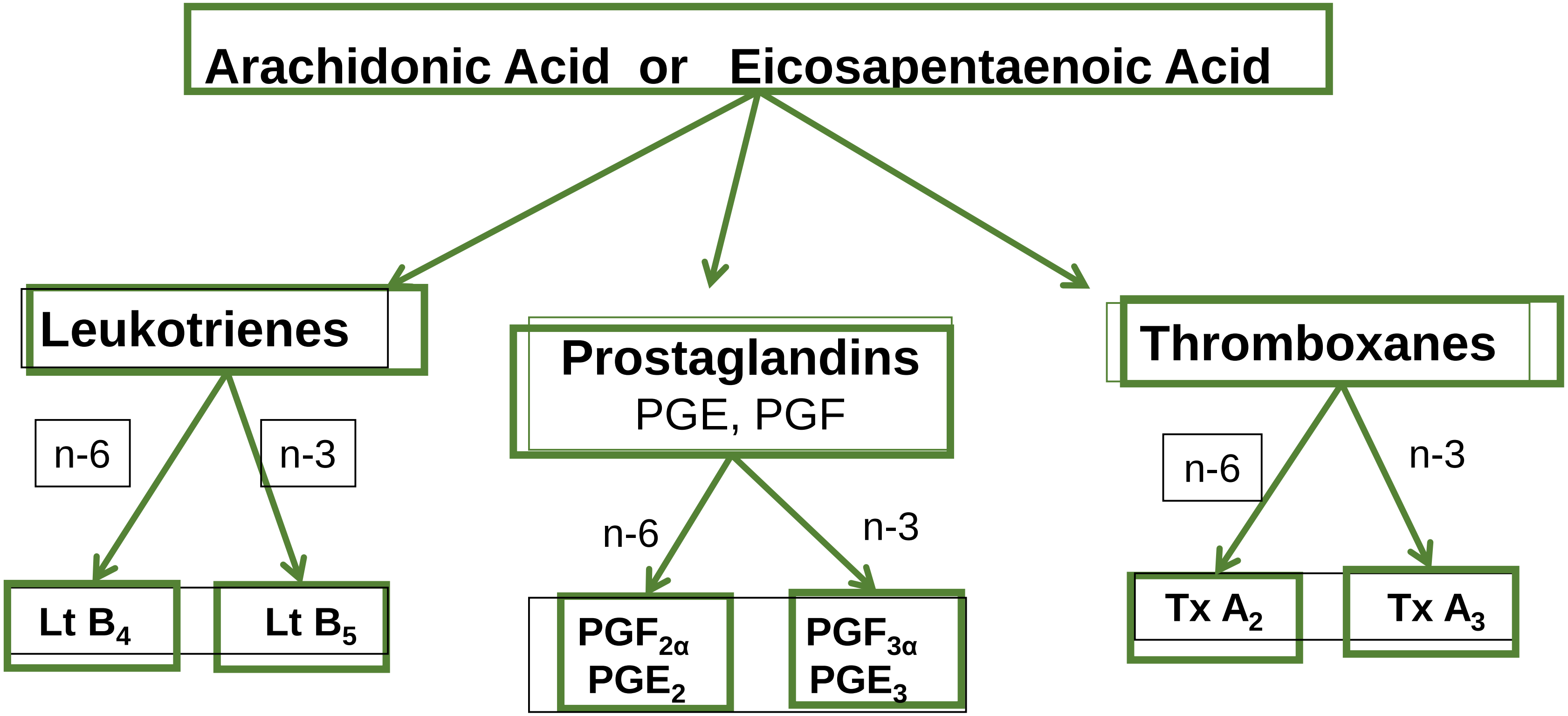
Polyunsaturated Fatty Acids (PUFA)

- PUFA contain more than one double bond

α-linolenic acid




Omega-6
Omega-3
C18:2 (Linoleic)
C18:3 (α-Linolenic)
Δ6 Desaturase (FADS2)
C18:3 γ
C18:4
Elongase
C20:3
C20:4
Δ5 Desaturase (FADS1)
C20:4 (Arachidonic)
C20:5 (Eicosapentenoic)
EICOSANOIDS
Pro-inflammatory
Anti-inflammatory



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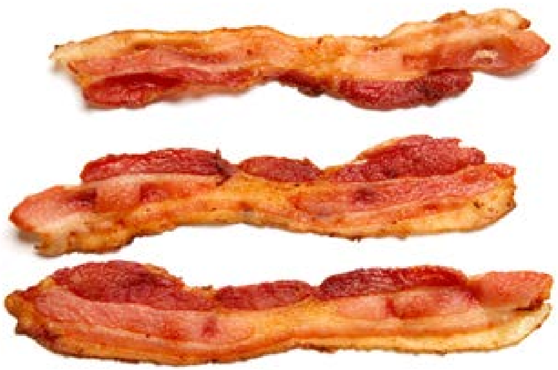
Why supplement the diet of a pig with omega-3 FA’s?

- Enrich the pork with omega-3 FA’s and thus benefit the consumer



- Allow the pig to take advantage of the physiological benefits of omega-3 FA’s

Enriching pork with omega-3 FA's

Journal of Clinical Medicine

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PMCID: PMC4693156

Pork as a Source of Omega-3 (*n*-3) Fatty Acids

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Important

- The pig is not a cow
  - Tissue (and milk) fat reflects dietary fat
    - 18:3 → 20:5 and 22:6??

Challenges

- Regulatory
- Effects on meat quality
- Consumer acceptance

Why supplement the diet of a pig with omega-3 FA's?

- Enrich the pork with omega-3 FA's and thus benefit the consumer

- Allow the pig to take advantage of the physiological benefits of omega-3 FA's

PUFA's and the sow

Background

- Sow mobilizes body fat to meet the energetic demands of lactation
- Hypophagia at farrowing contributes to negative energy balance of the sow
- Excessive loss of body weight affects lactation and reproductive performance
- Evidence that long chain PUFA affects activity of hormone-sensitive lipase, energy mobilization (Tilton et al. 1999) and moreover, differential response to n-6 and n-3 fatty acids for genes affecting energy metabolism in adipose tissue (Papapoulos et al. 2008)

PUFA's and the sow

Objectives

A series of experiments were conducted to determine if supplementation of the sow's diet with omega-3 FA's would:

- Decrease negative energy balance by decreasing tissue mobilization and improving feed intake post-partum
- Improve piglet growth and viability

Determine if the results are dependent on the n6:n3 ratio

Previous experiments had shown that the fatty acid content of sows' milk reflected diet fatty acid content, with slight increases in DHA and EPA when sows when the n6:n3 ratio was 5:1 Eastwood et al. 2014

Experimental Diets - Gestation

	Dietary Treatment Based on Fatty Acid Ratios (n-6 to n-3)				
Ingredient (% as fed)	**Control**	**10:1**	**5:1**	**1:1**	**1:1 Fish**
Barley	69.9	72.2	66.5	57.5	70.0
Wheat	9.6	7.0	12.0	19.0	8.9
Corn	-	-	1.5	4.4	-
Flaxseed	-	-	-	5.0	-
Soybean Meal	12.6	11.4	8.3	5.0	12.7
Canola Meal	1.6	1.4	-	-	1.6
Flaxseed Meal	-	1.8	6.0	5.4	-
Tallow	**3.5**	**-**	**-**	**-**	**-**
Canola Oil	**-**	**0.7**	**-**	**-**	**-**
Corn Oil	**-**	**2.6**	**2.3**	**0.4**	**0.1**
Flax Oil	**-**	**-**	**0.6**	**0.5**	**-**
Herring Oil	**-**	**-**	**-**	**-**	**3.9**

Eastwood et al. 2014

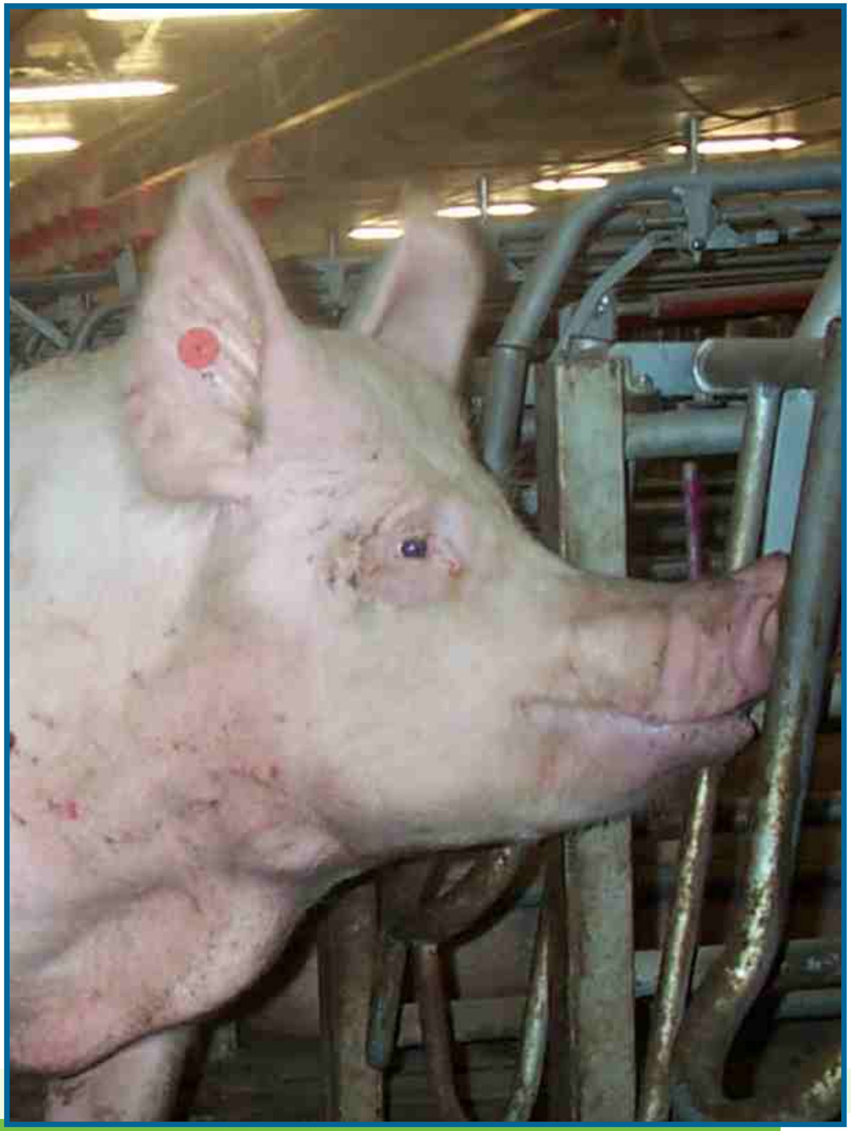
Experimental Diets - Gestation

	Dietary Treatment Based on Fatty Acid Ratios (n-6 to n-3)				
Chemical Analysis	**Control**	**10:1**	**5:1**	**1:1**	**1:1 Fish**
Ether Extract (%)	4.5	4.6	4.7	5.0	5.5
Total SFA (g/kg diet)	17.3	8.8	8.3	7.8	10.3
Total PUFA (g/kg diet)	16.5	29.5	30.5	33.0	28.2
Total n-3 (g/kg diet)	1.8	2.9	4.9	14.2	4.8
Total n-6 (g/kg diet)	14.7	29.6	25.7	18.9	23.4
n-6 to n-3 Ratio	**8:1**	**9:1**	**5:1**	**1:1**	**5:1**

Total n-3 90% C18:3 n3, 10% 20:5 n3 and 22:6 n3

Eastwood et al. 2014

Results



Results – Cycle 1

	Dietary Treatment					Statistics	
Production Parameter	**Control**	**10:1**	**5:1**	**1:1**	**5:1 Fish**	**SEM**	**P <**
Average Wean Weight (kg)	8.2^{ab}	8.6^{a}	8.6^{a}	8.0^{b}	7.8^{b}	0.19	0.02

Eastwood et al. 2014

Results – Cycle 2

	Dietary Treatment					Statistics	
Production Parameter	**Control**	**10:1**	**5:1**	**1:1**	**5:1 Fish**	**SEM**	**P <**
Sow ADFI (kg)	7.5[a]	7.4[a]	7.6[a]	7.5[a]	6.8[b]	0.20	0.04
Average Birth Weight (kg)	1.5[a]	1.4[ab]	1.5[a]	1.4[ab]	1.3[b]	0.05	0.05
Total Litter Wean Wt (kg)	88.7[a]	88.6[a]	90.4[a]	83.0[ab]	77.0[b]	2.88	0.01
Average Wean Weight (kg)	8.8[a]	8.7[ab]	9.2[a]	8.7[ab]	8.2[b]	0.21	0.04

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Results – Cycle 2

- Dietary treatment had no effects on:

Parameter	P <
Piglets born	0.84
Colostrum IgA (mg/ml)	0.84
Post-Suckle Serum IgA (mg/ml)	0.96
Colostrum IgG (mg/ml)	0.90
Post-Suckle Serum IgG (mg/ml)	0.93

Eastwood et al. 2014

Summary

- Sows consuming the fish oil diet ate less feed, had reduced piglet birth weights and weaning weights when compared to the other treatment groups

- A 5:1 ratio fed to sows did not affect birth weights or return to estrus intervals; however, a modest effect on litter weaning weights

Eastwood et al. 2014

PUFA's and the sow

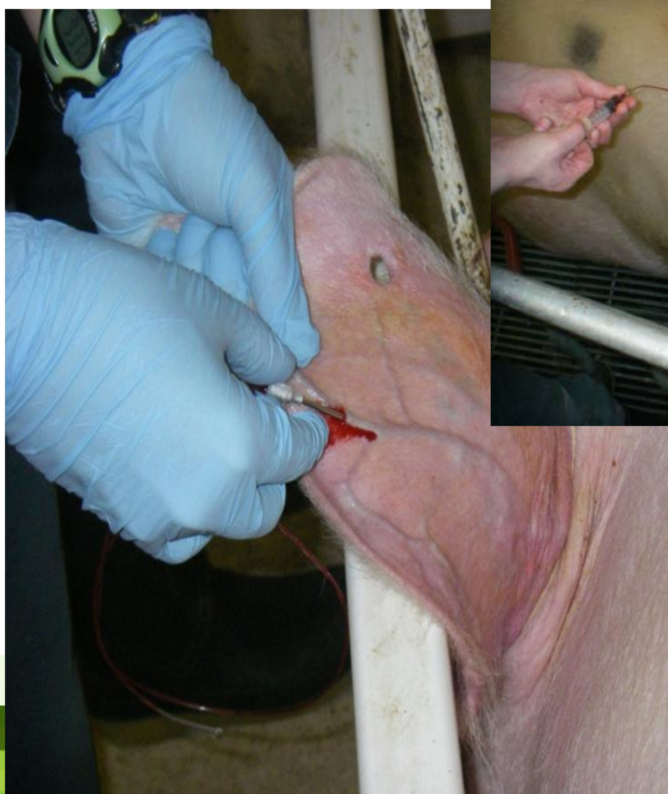
Background

- Sow mobilizes body fat to meet the energetic demands of lactation (lactational homeorhesis)
- Hypophagia at farrowing contributes to negative energy balance of the sow
- Excessive loss of body weight affects lactation and reproductive performance
- Evidence that long chain PUFA affects activity of hormone-sensitive lipase, energy mobilization (Tilton et al. 1999) and moreover, differential response to n6 and n3 fatty acids for genes affecting energy metabolism in adipose tissue (Papapoulos et al. 2008)

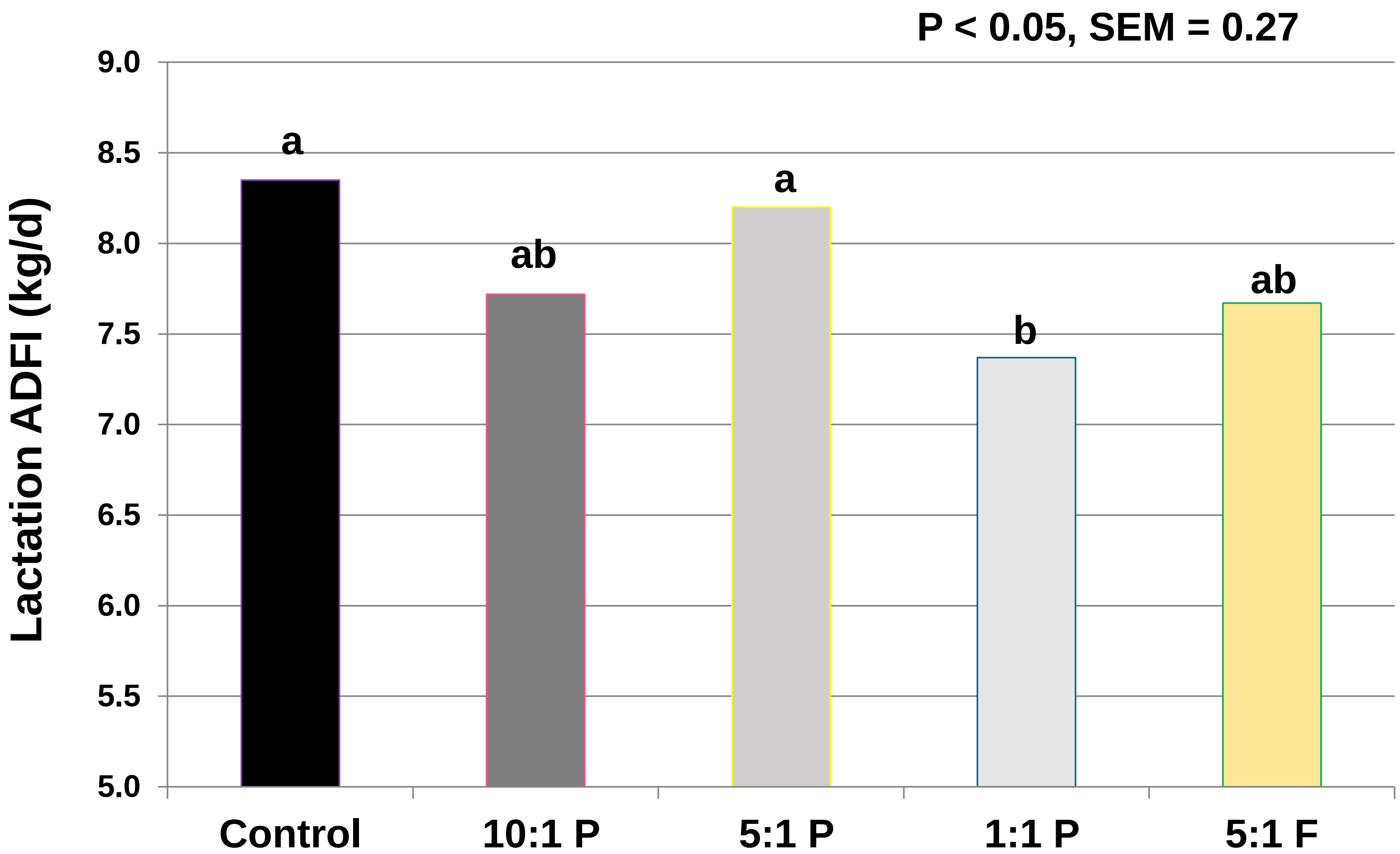
- **Specific Objectives:**
  - To characterize how the n6:n3 ratio in sow diets influences whole body metabolism and milk production by looking at:
    - Milk energy output
    - Piglet growth rate
    - **Sow feed intake**
    - Adipose tissue mobilization

Adipose Tissue “Responsiveness”:

- Utilized similar diets as described previously, 11 months
- Glucose and epinephrine challenges



LACTATION ADFI (kg/d)



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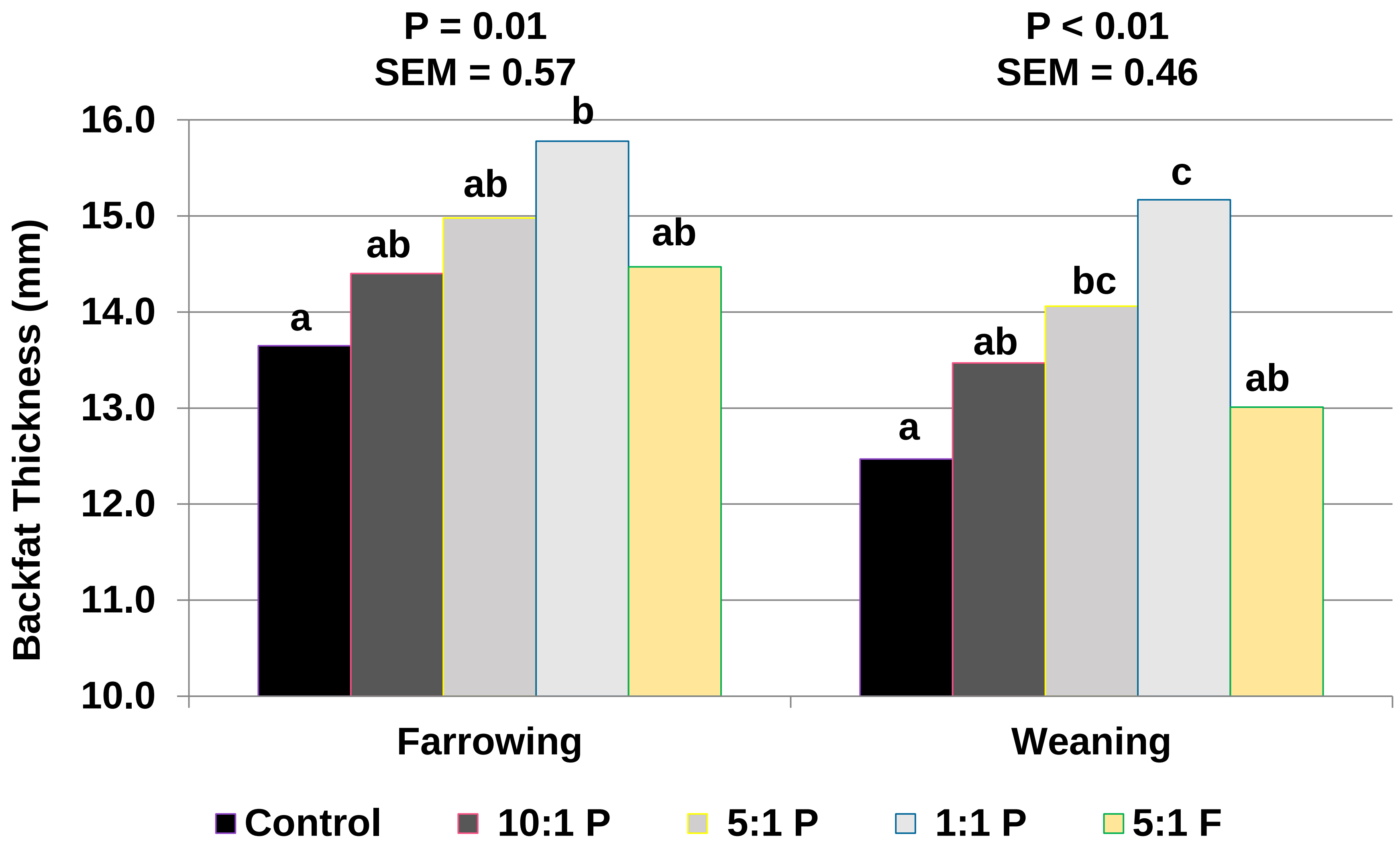
BACKFAT THICKNESS (mm)



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PRE-CHALLENGE BLOOD

	10:1 P	1:1 P	SEM	P <
[NEFA], uM	93.27	240.02	74.152	0.16
[Glycerol], mg/dl	0.40	0.81	0.214	0.20
Fasted [glucose], mg/dl	64.67	63.54	5.707	0.88
[C-Peptide], ng/ml	0.30	0.25	0.070	0.58

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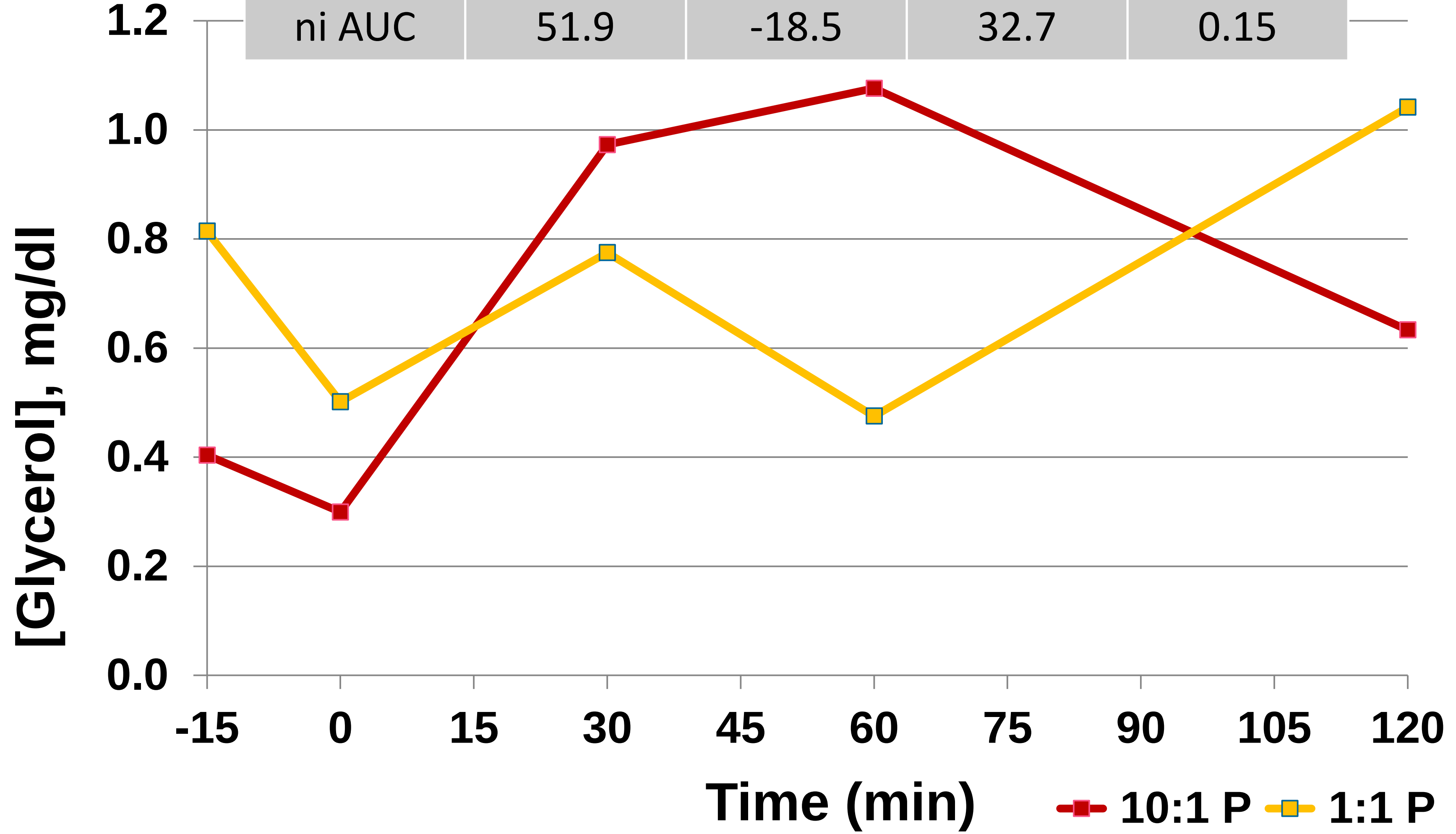
EPINEPHRINE CHALLENGE - GLYCEROL

	10:1 P	1:1 P	SEM	P <
ni AUC	51.9	-18.5	32.7	0.15



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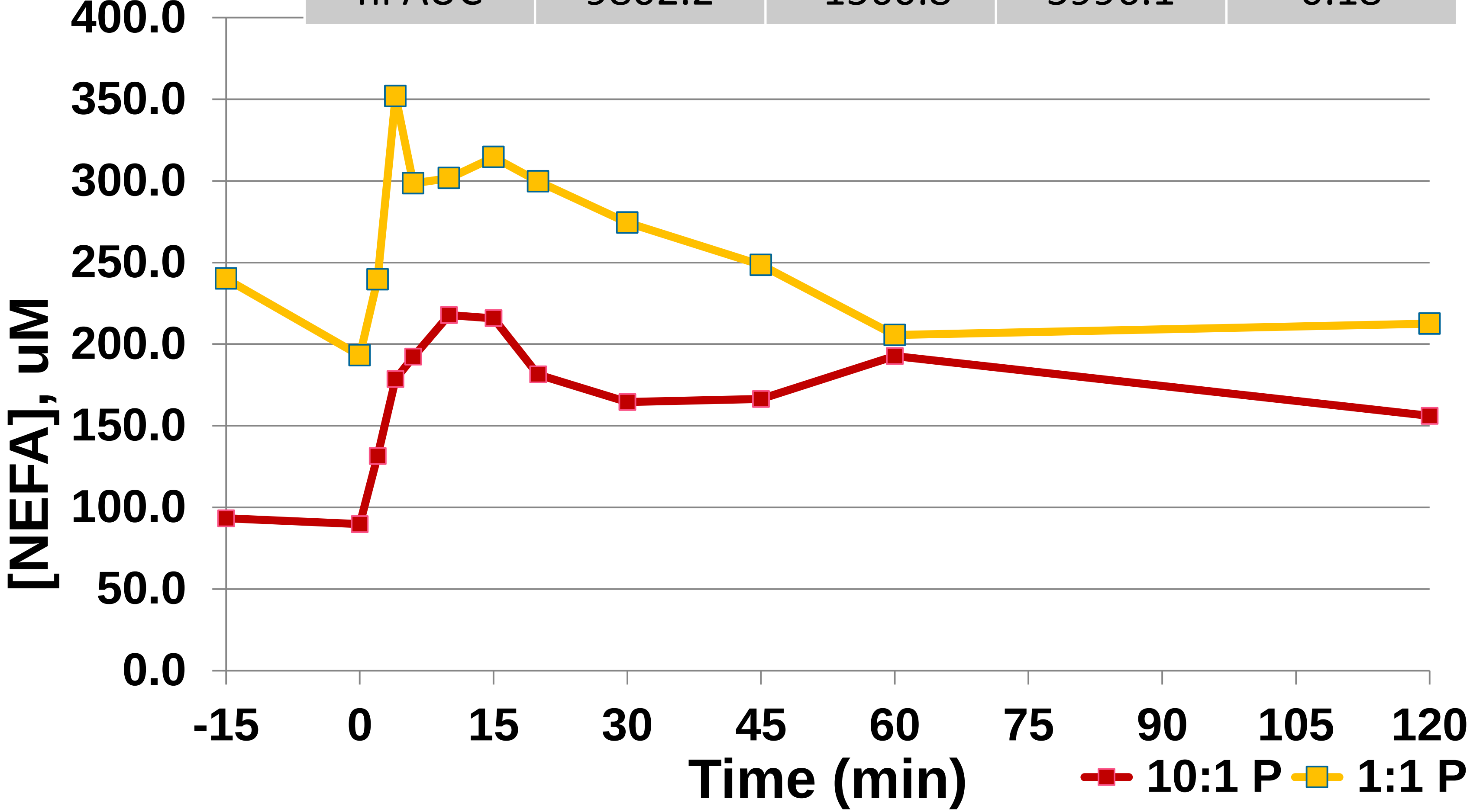
EPINEPHRINE CHALLENGE - NEFA

	10:1 P	1:1 P	SEM	P Value
ni AUC	9802.2	-1560.8	5996.1	0.18



1:1 sows had a higher NEFA background

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GLUCOSE CHALLENGE

- Glucose and C-Peptide concentrations increased in response to glucose infusion
- No dietary effects as sows on both diets responded similarly ($P > 0.1$)

Eastwood et al. 2016

LEPTIN

	10:1 P	1:1 P	SEM	P Value
Day 5 Leptin, ng/ml HE	3.24	3.27	0.279	0.93
Day 15 Leptin, ng/ml HE	3.24	3.82	0.210	0.07

- Day 15 leptin correlated with:
  - NEFA; r = 0.46, P = 0.07
  - Glycerol; r = 0.45, P = 0.1
  - Weaning BF thickness; r = 0.55, P = 0.03

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CONCLUSIONS

- Comparable piglet growth, reduced sow feed intake, increased plasma NEFA and reduced response to the epinephrine challenge implies that sows consuming the 1:1 n6:n3 FA ratio were mobilizing body reserves to supply nutrients in their milk.

- Reducing the dietary n6:n3 FA ratio below an optimal point puts sows in a state of increased body fat mobilization, which in turn would have negative impacts on sow body condition and longevity

- We hypothesized that reducing the n6:n3 FA ratio in sow diets would alleviate hypophagia post farrowing and improve milk production (energy output)
  - Feed intake was highest in the 5:1 fed sows, negative effects below that
  - Piglet growth and milk production were unaffected

Eastwood et al. 2016

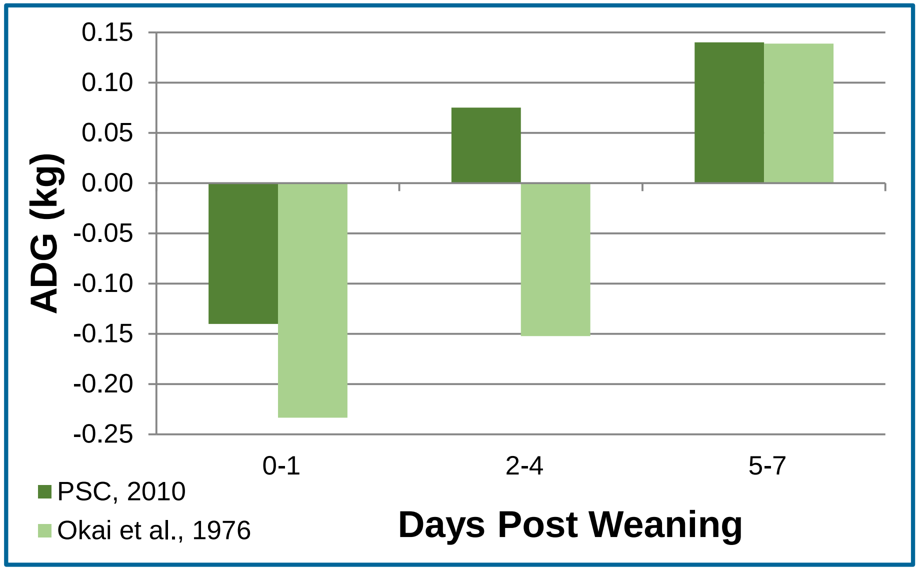
Feeding the sow diets with varying n6:n3 ratios had no effect on piglet ADG during lactation

- However, other work at PSC and in the literature provides conflicting results

- What about the newly weaned piglet?

Weaning

- Stressful!!
  - Environmental
  - Social
  - Nutritional
- Post-weaning growth lag



- Maximize nursery performance
  - Growth
  - Feed intake
  - Health

- Using diets devoid of in-feed antibiotics

Impact on piglet

- Reducing plant based n6:n3 ratios in pig diets can:
  - Improve piglet growth prior to weaning
  - Increase conversion of ALA into EPA
  - Alter febrile and cytokine responses in piglets challenged with LPS
- A literature review reveals conflicting results:
  - Positive, negative and no change
  - **Ratio often not accounted for, diets high in n6**

Does the anti-inflammatory response to n3 fatty acids depend on the ratio with n6?

- Newly weaned piglets fed diets varying in n6:n3 ratios and amounts
- Challenged with LPS

Stage 2 Diets

	Control	3.5/10	5/10	3.5/5	3.5/1
Fat content, %	**3.5**	**3.5**	**5**	**3.5**	**3.5**
n6:n3	**10:1**	**10:1**	**10:1**	**5:1**	**1:1**
Total n3, g/kg	2.4	2.7	3.4	5.0	14.0
Total n6, g/kg	1.8	2.8	3.5	2.7	17.0
Total PUFA, g/kg	20.0	30.5	38.0	31.5	30.1
n6:n3 Ratio	7.32	10.30	10.23	5.36	1.22

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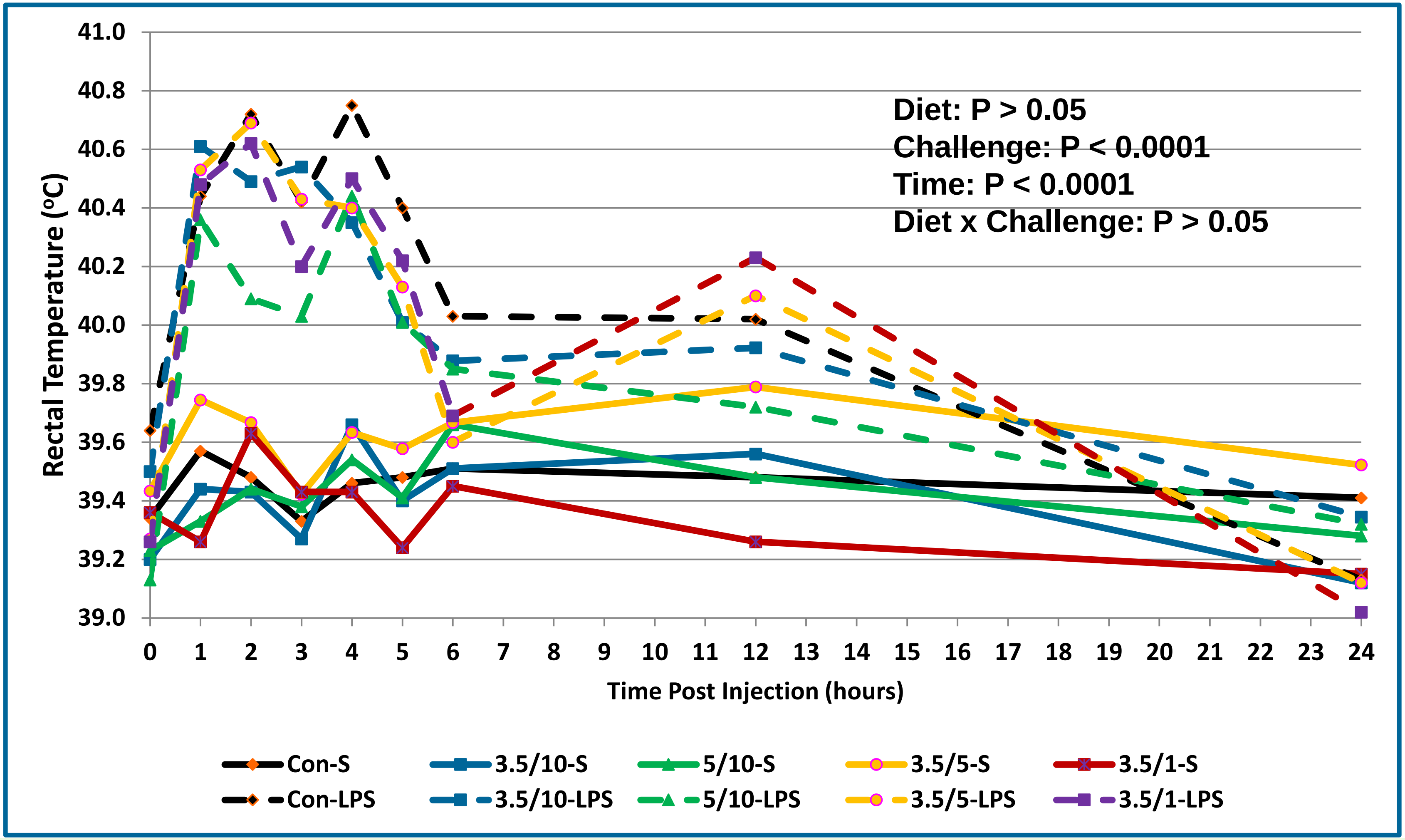
Febrile Response



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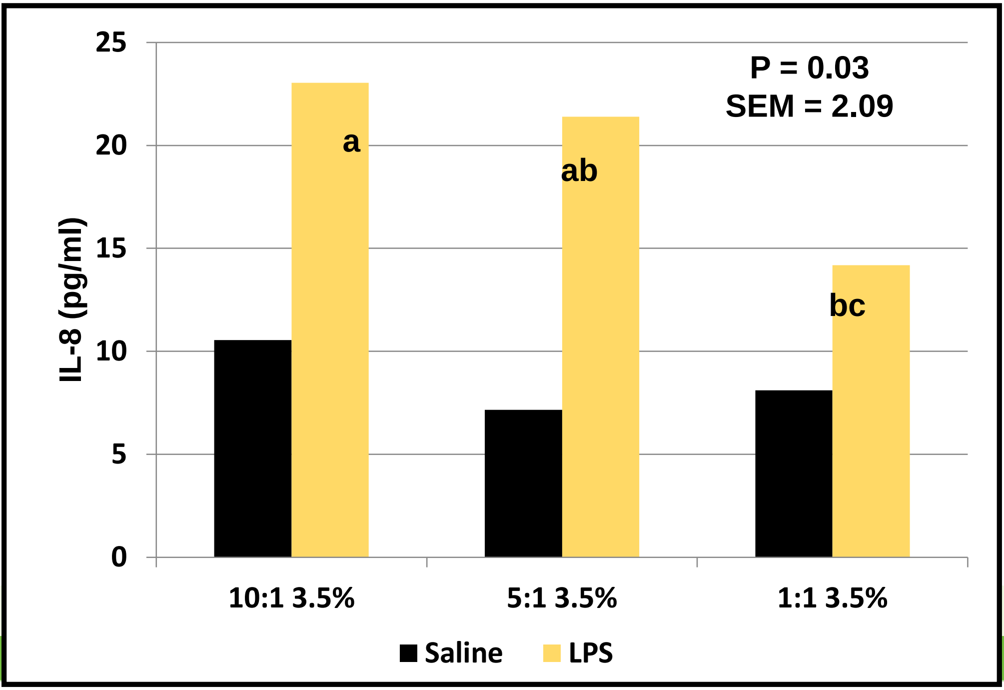
BUN and Cytokines

- Pigs challenged with LPS had elevated BUN and serum cytokine concentrations relative to saline pigs (P > 0.05)

- No dietary effects on BUN, IL-1β, IL-6 or TNFα

- Serum IL-8
  - Unaffected by increasing dietary n3 (with constant ratio)
  - In LPS challenged pigs
  - Decreased with decreasing n6:n3 ratio



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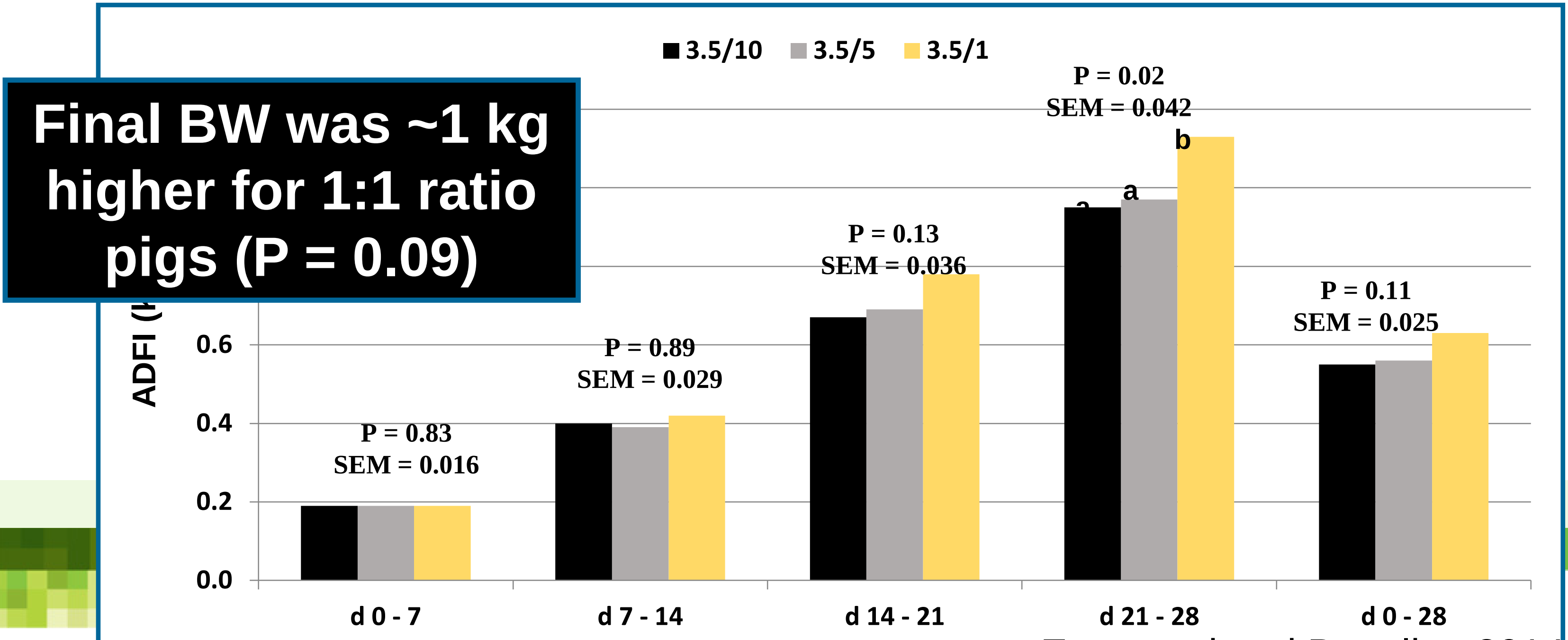
Animal Performance

- Saturated vs. unsaturated diets
  - No effect on ADG, ADFI or G:F
- Increasing n3 amount with constant 10:1 ratio
  - No effect on ADG, ADFI or G:F
- Decreasing n6:n3 ratio with constant 3.5% total fat
  - No effect on ADG or G:F



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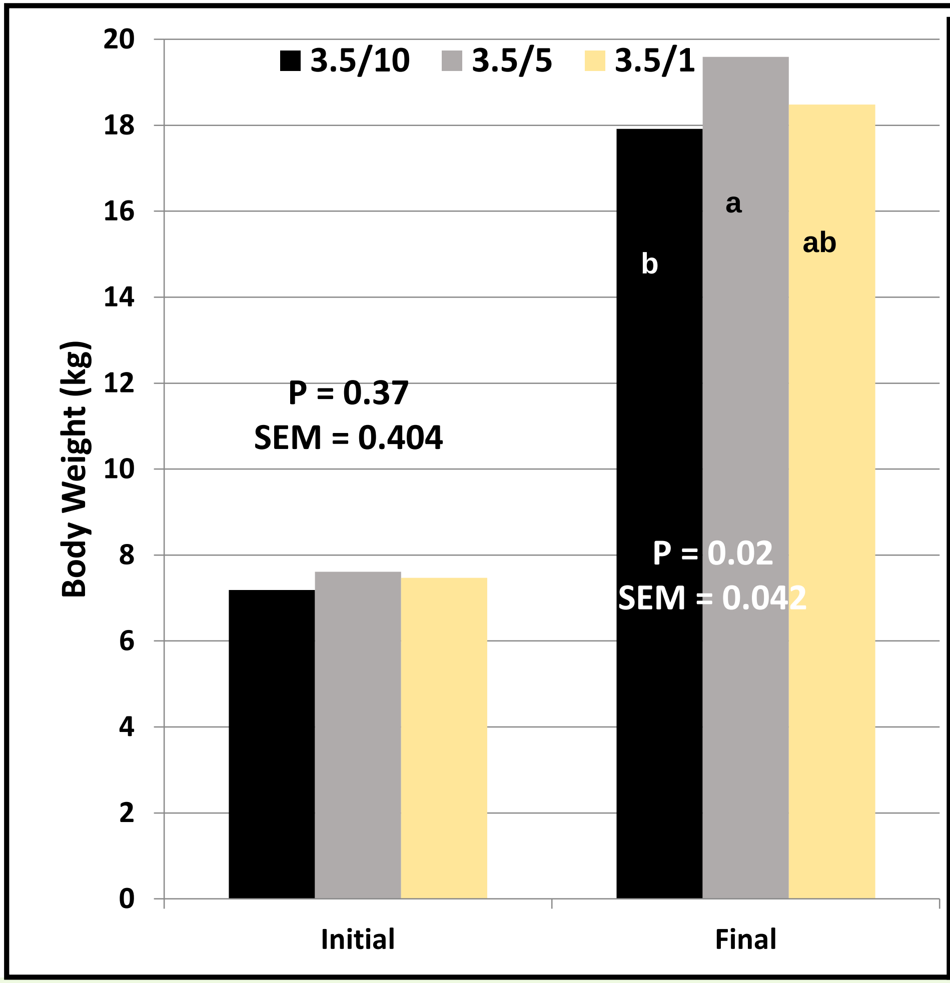
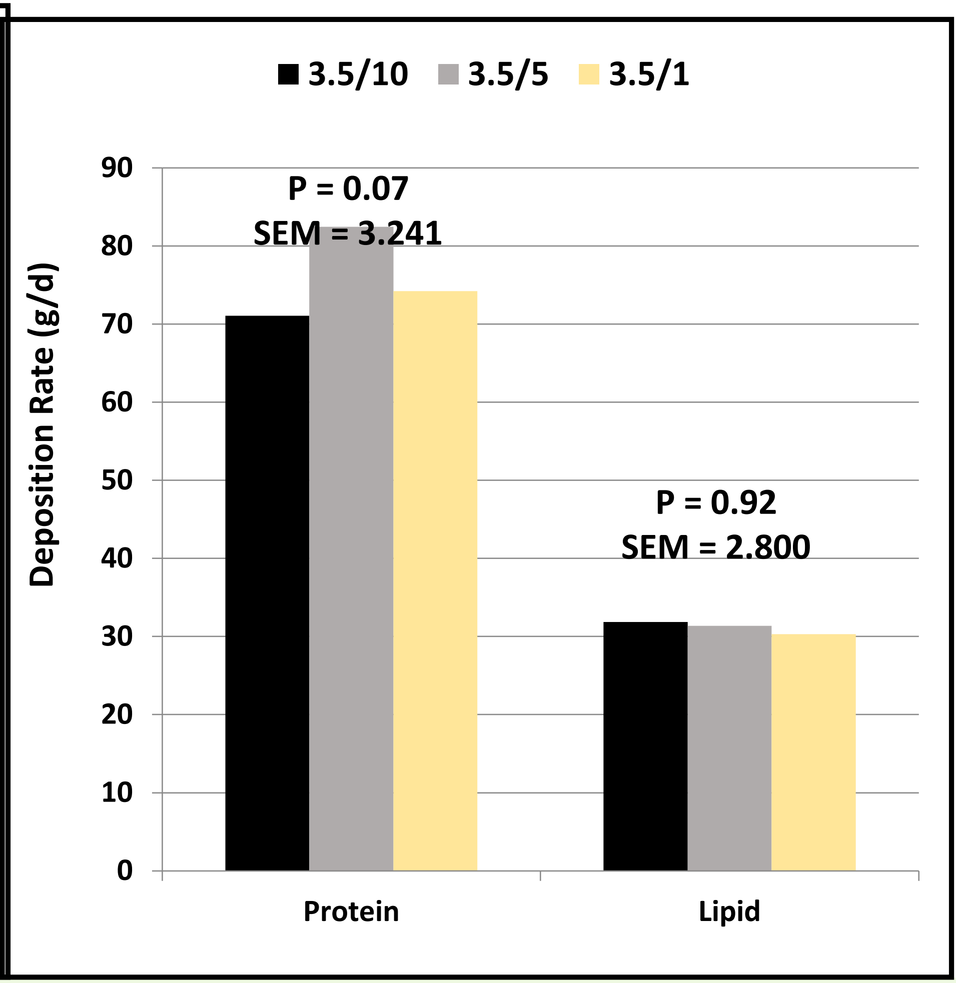
BW and Carcass Composition





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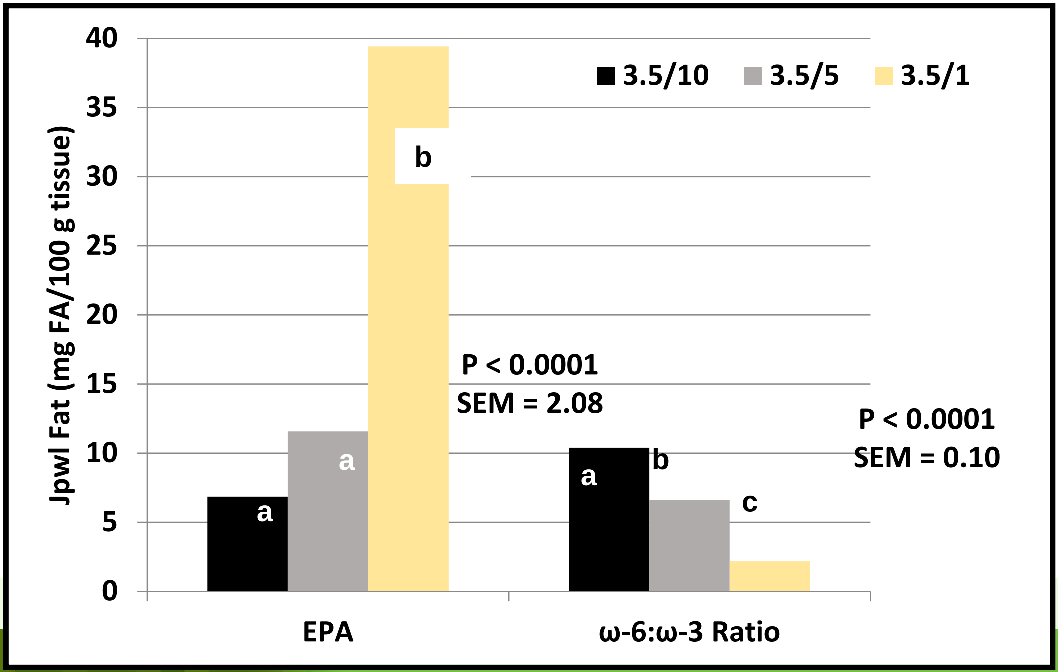
Jowl Fatty Acid Profiles

- Increasing the amount of dietary fat (with constant ratio) did not affect the FA profile

- Reducing the n6:n3 ratio (with constant fat level):
  - Increased n3 overall (including ALA and EPA)
  - Decreased n6 overall (including LA and AA)
  - DHA unaffected



ω-6:ω-3 ratio	
Diet	**Jowl**
10.30	10.38
5.36	6.59
1.22	2.17

Eastwood and Beaulieu 2014

Summary and Conclusions

- Changing the dietary ω-6 to ω-3 fatty acid ratio impacts nursery pig inflammatory responses more than increasing ω-3 intake alone.
- Reducing the dietary ω-6:ω-3 ratio in nursery pigs may reduce their overall inflammatory response during weaning.
  - This may explain why pigs fed the same diets in our previous trial had improved protein deposition when fed diets with lower ω-6:ω-3 ratios
  -
  - The pig would require less protein to be diverted to the immune system for synthesis of inflammatory proteins.

Overall conclusion and future research

- There is evidence that reducing the n6:n3 fatty acid ratio improves protein deposition in growing pigs, possibly by reducing inflammatory response

- Further research is required to determine if this is due to the conversion of C18:3 n3 to C20:5 n3 or intake of small amounts of C20:5 n3

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O & T Farms Ltd.
Vandeputte Group

Sask PORK
ALBERTA PORK
ONTARIO PORK
Manitoba Pork

FADS1 and FADS2

- No effect of altering ratio, amount or type of fat on FADS1 or FADS2 enzyme expression

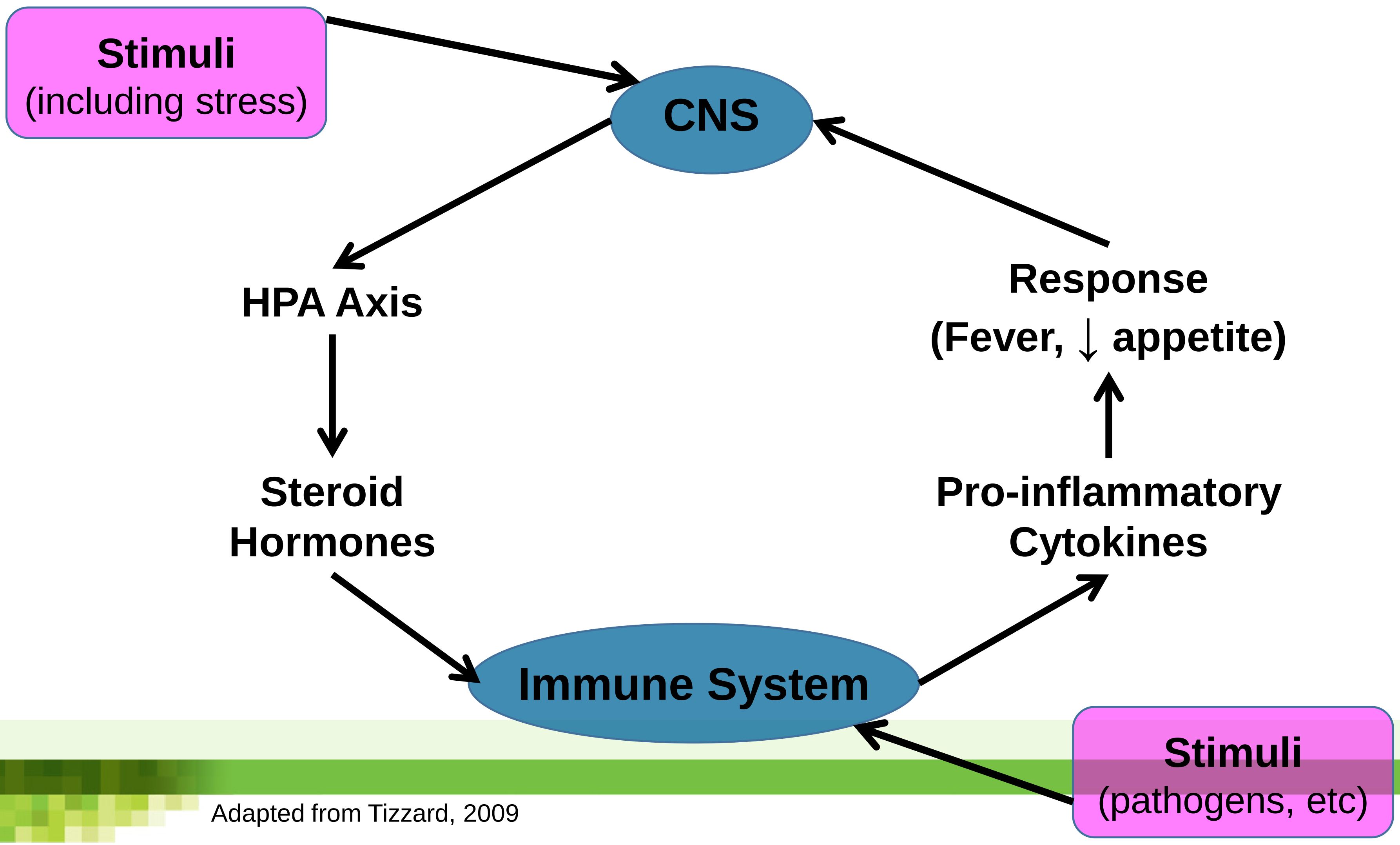
Diet Digestibility

- No effect of altering fat type or fat amount on DM, N or crude fat digestibility
- Tendency for increased DM digestibility with decreasing ω-6:ω-3 ratio

ACKNOWLEDGEMENTS

Results

Stress and the Immune System



Adapted from Tizzard, 2009

Cytokines

- Produced by monocytes and macrophages in response to immune challenges
  - IL-1, IL-6, IL-8, TNFα, etc
- Function influenced by PUFA's via alterations to
  - intracellular signaling pathways
  - transcription factor activity
  - gene expression
- Cytokine overproduction can lead to
  - muscle breakdown
  - reduced protein synthesis
  - diversion of nutrients to the formation of more immune cells
- Possibly affecting growth, performance and overall profit

Summary

- Animal performance (ADG, ADFI, G:F) was unaffected by dietary treatment.
- LPS challenged pigs had reduced ADG and ADFI, elevated rectal temperatures and increased BUN and serum cytokine concentrations relative to the saline injected pigs.
- Regardless of challenge, serum IL-8 concentrations decreased when pigs were fed diets with decreasing ω-6:ω-3 ratios. Altering the ω-3 amount had no effect.
- When total fat was held constant, IL-8 responses to the LPS challenge were lower in pigs fed the 1:1 ratio diet relative to those consuming the 10:1 diet, and was similar to that of saline injected pigs regardless of diet.