Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

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THE FATTY ACID FORUM

HOT TOPIC

UNIVERSITY OF FLORIDA
IFAS Extension
**HOT TOPIC**

Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

Effect of Supplemental FA on Performance of Dairy Cows

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>SFA</th>
<th>EFA</th>
<th>T*P</th>
<th>Fat</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI, kg/d</td>
<td>18.0 ± 0.7</td>
<td>19.3 ± 0.5</td>
<td>18.1 ± 0.6</td>
<td>0.01</td>
<td>0.42</td>
<td>0.12</td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>31.7 ± 1.0</td>
<td>31.8 ± 0.9</td>
<td>34.1 ± 0.9</td>
<td>0.07</td>
<td>0.27</td>
<td>0.06</td>
</tr>
<tr>
<td>Milk/DMI</td>
<td>1.83 ± 0.07</td>
<td>1.70 ± 0.06</td>
<td>1.95 ± 0.06</td>
<td>0.03</td>
<td>0.94</td>
<td>0.01</td>
</tr>
</tbody>
</table>

1 – T*P → Interaction between treatment and parity; Fat → Control vs. SFA + EFA; FA → SFA vs. EFA

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Effect of Supplemental FA on Performance of Dairy Cows

Silvestre et al. (2011) J. Dairy Sci. 94:2285–2301

![Graphs showing TNF-α and IL-1β levels with and without LPS and mass increased conditions.](image)

Silvestre et al. (2011) J. Dairy Sci. 94:2285–2301
Evaluate the impacts of altering the ratio of n-6 to n-3 FA of diets fed to early lactation cows on:
• Lactational performance
• Acute phase response to an intramammary LPS challenge
• 45 multiparous cows blocked by parity (2 vs. > 2) and milk yield between 6 and 10 DIM and, within each block, randomly assigned to 1 of 3 treatments
  – TMR with a ratio of n6:n3 FA of 4:1 – R4
  – TMR with a ratio of n6:n3 FA of 5:1 – R5
  – TMR with a ratio of n6:n3 FA of 6:1 – R6
• The FA profile of diets was altered by incorporating Ca salts of fish oil (Strata), safflower oil (Prequel) and palm oil (EnerGII)
• Cows were fed a common diet for the first 14 DIM
• Lactation performance evaluated from day 15 to 106 postpartum (13 weeks)
  - Cows were milked twice daily and no bST was used
  - Yields of milk, fat, protein and lactose measured daily and averaged weekly
  - BW was measured twice daily and averaged weekly
## Hot Topic

**Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response**

### Dietary Ingredients

<table>
<thead>
<tr>
<th>Ingredients, % DM</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn Silage</td>
<td>18.7</td>
<td>18.7</td>
<td>18.7</td>
</tr>
<tr>
<td>Bermuda Grass Silage</td>
<td>9.0</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Alfalfa Hay</td>
<td>6.1</td>
<td>6.1</td>
<td>6.1</td>
</tr>
<tr>
<td>Corn Grain, Finely Ground</td>
<td>13.8</td>
<td>13.8</td>
<td>13.8</td>
</tr>
<tr>
<td>Citrus Pulp</td>
<td>10.1</td>
<td>10.1</td>
<td>10.1</td>
</tr>
<tr>
<td>Soybean Hulls</td>
<td>20.3</td>
<td>20.3</td>
<td>20.3</td>
</tr>
<tr>
<td>Soybean Meal</td>
<td>10.1</td>
<td>10.1</td>
<td>10.1</td>
</tr>
<tr>
<td>Cooker-Processed SBM</td>
<td>5.7</td>
<td>5.7</td>
<td>5.7</td>
</tr>
<tr>
<td>Molasses</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td>MinVit Premix</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Ca Salts of Palm Oil</td>
<td>0.73</td>
<td>0.65</td>
<td>0.53</td>
</tr>
<tr>
<td>Ca Salts of Safflower Oil</td>
<td>0</td>
<td>0.37</td>
<td>0.70</td>
</tr>
<tr>
<td>Ca Salts of Fish Oil</td>
<td>0.70</td>
<td>0.41</td>
<td>0.20</td>
</tr>
</tbody>
</table>
## Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

### Chemical Composition of Diets

<table>
<thead>
<tr>
<th>Nutrient Content, DM Basis (± SD)</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NE(_L), 1 \text{ Mcal/kg}</strong></td>
<td>1.62</td>
<td>1.62</td>
<td>1.62</td>
</tr>
<tr>
<td><strong>CP, %</strong></td>
<td>16.6 ± 0.8</td>
<td>16.6 ± 0.8</td>
<td>16.5 ± 0.8</td>
</tr>
<tr>
<td><strong>Starch, %</strong></td>
<td>17.3</td>
<td>17.3</td>
<td>17.3</td>
</tr>
<tr>
<td><strong>Non-Fibrous Carbohydrates, %</strong></td>
<td>35.4 ± 1.9</td>
<td>35.4 ± 2.0</td>
<td>35.5 ± 1.9</td>
</tr>
<tr>
<td><strong>Acid Detergent Fiber, %</strong></td>
<td>16.0 ± 0.9</td>
<td>15.9 ± 0.9</td>
<td>15.6 ± 0.9</td>
</tr>
<tr>
<td><strong>Neutral Detergent Fiber, %</strong></td>
<td>38.4 ± 2.3</td>
<td>38.4 ± 2.3</td>
<td>38.1 ± 2.3</td>
</tr>
<tr>
<td><strong>NDF from Forage, %</strong></td>
<td>17.1 ± 0.7</td>
<td>17.1 ± 0.7</td>
<td>17.1 ± 0.7</td>
</tr>
<tr>
<td><strong>Fatty Acids, %</strong></td>
<td>3.66 ± 0.15</td>
<td>3.82 ± 0.17</td>
<td>3.88 ± 0.16</td>
</tr>
</tbody>
</table>

1 Estimated based on nutrient analysis of ingredients and adjusted for 24kg DM intake (NRC, 2001)
On d 75 postpartum, cows with SCC < 300,000/mL in the preceding 10 d and negative CMT on the day of challenge were used (n = 39 cows).

Approximately 3 h after the morning milking, 10 µg of LPS (E. coli O111:B4; Sigma) diluted in 10 mL of sterile PBS was infused via teat canal.

Milk samples were collected at 0, 2, 4, 6, 8, 14, 24, 48, 72 and 96 h after the infusion.
- Infused quarter
- Composite of 3 non-infused quarters
Blood was sampled multiple times
- Acute phase proteins
- Cytokines
- Insulin, glucose
- Neutrophil function

Rectal temperature measured

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Intramammary LPS Challenge

![Graph showing time course of LPS infusion, acute phase response, body temperature, milk sampling, neutrophil phagocytosis, and oxidative burst.](graph.png)
Data were analyzed by the GLIMMIX procedure of SAS fitting either a normal or Poisson distribution. Data were evaluated for normality of residuals and transformed if needed. Back-transformed values are presented.

Repeated measures
- Fixed effects: Pre-treatment covariate value + Treatment + Time + Treatment x Time
- Random effect: Cow(Treatment)

Orthogonal polynomial contrasts were used to test
- Linear (R4 vs. R6)
- Quadratic (R4+R6 vs. R5)
## Hot Topic
Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

### Lactation Performance

<table>
<thead>
<tr>
<th>Treatment¹</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>SEM</th>
<th>TRT</th>
<th>Lin</th>
<th>Quad</th>
</tr>
</thead>
<tbody>
<tr>
<td>DM Intake, kg/d</td>
<td>26.1</td>
<td>24.6</td>
<td>24.7</td>
<td>0.5</td>
<td>0.07</td>
<td>0.05</td>
<td>0.17</td>
</tr>
<tr>
<td>Fatty Acid Intake³, g/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linoleic</td>
<td>298.1</td>
<td>329.5</td>
<td>369.4</td>
<td>8.6</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.69</td>
</tr>
<tr>
<td>EPA + DHA</td>
<td>20.3</td>
<td>14.9</td>
<td>10.0</td>
<td>0.3</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.65</td>
</tr>
<tr>
<td>Total n-6</td>
<td>300.6</td>
<td>332.0</td>
<td>371.9</td>
<td>8.6</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.69</td>
</tr>
<tr>
<td>Total n-3</td>
<td>76.3</td>
<td>67.3</td>
<td>62.8</td>
<td>1.7</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.27</td>
</tr>
<tr>
<td>Ratio of n-6 to n-3</td>
<td>3.9</td>
<td>4.9</td>
<td>5.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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¹ Treatment: R4, R5, R6
² TMR Intake, kg/d
³ Fatty Acid Intake, g/d
Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

DM Intake

Week postpartum

- R4: 26.1 ± 0.50
- R5: 24.6 ± 0.47
- R6: 24.7 ± 0.48

TRT: P = 0.07
Week: P < 0.0001
TRT*Week: P = 0.47
Linear: P = 0.05
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**Milk Yield**

- **TRT**: \( P = 0.02 \)
- **Week**: \( P < 0.001 \)
- **TRT*Week**: \( P = 0.66 \)
- **Linear**: \( P < 0.01 \)

- **R4**: \( 46.8 \pm 0.9 \)
- **R5**: \( 44.7 \pm 0.9 \)
- **R6**: \( 43.3 \pm 0.9 \)
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3.5% FCM

<table>
<thead>
<tr>
<th>TRT</th>
<th>Week postpartum</th>
<th>TRT: P &lt; 0.01</th>
<th>Week: P &lt; 0.001</th>
<th>TRT*Week: P = 0.71</th>
<th>Linear: P &lt; 0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>R4</td>
<td>3</td>
<td>48.0 ± 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td>4</td>
<td>45.4 ± 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td>5</td>
<td>43.4 ± 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Feed Efficiency

TRT: $P = 0.04$
Week: $P < 0.001$
TRT*Week: $P = 0.95$
Linear: $P = 0.01$

- $R4 = 1.88 \pm 0.03$
- $R5 = 1.85 \pm 0.03$
- $R6 = 1.78 \pm 0.03$
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Body Weight and BCS

**Daily Body Weight**
- R4, R5, R6
- TRT: P = 0.40
- Week: P < 0.001
- TRT*Week: P = 0.80
- Linear: P = 0.44

**Weekly Body Condition**
- R4, R5, R6
- TRT: P = 0.07
- Week: P < 0.001
- TRT*Week: P = 0.70
- Linear: P = 0.19
- Quad: P = 0.07
# Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

## Milk Composition

<table>
<thead>
<tr>
<th>Ratio n6:n3 FA in the Diet</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>SEM</th>
<th>TRT</th>
<th>Wk</th>
<th>TRT*Wk</th>
<th>Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk Fat, %</td>
<td>3.64</td>
<td>3.58</td>
<td>3.55</td>
<td>0.05</td>
<td>0.42</td>
<td>&lt;0.01</td>
<td>0.23</td>
<td>0.19</td>
</tr>
<tr>
<td>Milk Fat, kg/day</td>
<td>1.71</td>
<td>1.60</td>
<td>1.53</td>
<td>0.03</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.69</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>True Protein, %</td>
<td>2.82</td>
<td>2.86</td>
<td>2.86</td>
<td>0.02</td>
<td>0.23</td>
<td>&lt;0.01</td>
<td>0.99</td>
<td>0.13</td>
</tr>
<tr>
<td>True Protein, kg/day</td>
<td>1.32</td>
<td>1.28</td>
<td>1.24</td>
<td>0.02</td>
<td>0.03</td>
<td>&lt;0.01</td>
<td>0.75</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Lactose, %</td>
<td>4.90</td>
<td>4.88</td>
<td>4.88</td>
<td>0.01</td>
<td>0.37</td>
<td>&lt;0.01</td>
<td>0.82</td>
<td>0.23</td>
</tr>
<tr>
<td>Lactose, kg/day</td>
<td>2.29</td>
<td>2.19</td>
<td>2.12</td>
<td>0.04</td>
<td>0.01</td>
<td>&lt;0.01</td>
<td>0.46</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Mcal/kg</td>
<td>0.69</td>
<td>0.69</td>
<td>0.68</td>
<td>0.01</td>
<td>0.68</td>
<td>&lt;0.01</td>
<td>0.18</td>
<td>0.38</td>
</tr>
<tr>
<td>Mcal/day</td>
<td>32.3</td>
<td>30.8</td>
<td>29.5</td>
<td>0.6</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.74</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
## Hot Topic
Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

Concentrations of Hormones & Metabolites in Plasma

<table>
<thead>
<tr>
<th>Treatment</th>
<th>R4</th>
<th>R5</th>
<th>R6</th>
<th>SEM</th>
<th>TRT</th>
<th>Lin</th>
<th>Quad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose, mg/dL</td>
<td>65.7</td>
<td>67.5</td>
<td>66.1</td>
<td>1.1</td>
<td>0.46</td>
<td>0.81</td>
<td>0.22</td>
</tr>
<tr>
<td>Urea N, mg/dL</td>
<td>12.4</td>
<td>11.0</td>
<td>12.4</td>
<td>0.4</td>
<td>0.04</td>
<td>0.93</td>
<td>0.01</td>
</tr>
<tr>
<td>NEFA³, µM</td>
<td>310.8</td>
<td>256.7</td>
<td>247.9</td>
<td>22.5</td>
<td>0.10</td>
<td>0.06</td>
<td>0.46</td>
</tr>
<tr>
<td>BHBA³, mg/dL</td>
<td>6.51</td>
<td>6.34</td>
<td>6.11</td>
<td>0.47</td>
<td>0.83</td>
<td>0.55</td>
<td>0.94</td>
</tr>
<tr>
<td>Insulin, ng/mL</td>
<td>0.47</td>
<td>0.50</td>
<td>0.52</td>
<td>0.05</td>
<td>0.73</td>
<td>0.44</td>
<td>0.89</td>
</tr>
<tr>
<td>IGF-I³, ng/mL</td>
<td>35.7</td>
<td>37.0</td>
<td>36.5</td>
<td>1.9</td>
<td>0.88</td>
<td>0.75</td>
<td>0.69</td>
</tr>
</tbody>
</table>
HOT TOPIC

Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response
Plasma & Milk Fatty Acid Composition

<table>
<thead>
<tr>
<th>FA (g/100g)</th>
<th>Treatment</th>
<th>SEM</th>
<th>TRT</th>
<th>Lin</th>
<th>Quad</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R4</td>
<td>R5</td>
<td>R6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plasma</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total n-6</td>
<td>50.85</td>
<td>52.66</td>
<td>53.30</td>
<td>0.54</td>
<td>0.01</td>
</tr>
<tr>
<td>Total n-3</td>
<td>7.09</td>
<td>5.46</td>
<td>4.76</td>
<td>0.34</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>n-6 to n-3 Ratio</td>
<td>7.60</td>
<td>9.84</td>
<td>11.33</td>
<td>0.40</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total n-6</td>
<td>2.90</td>
<td>3.13</td>
<td>3.45</td>
<td>0.14</td>
<td>0.03</td>
</tr>
<tr>
<td>Total n-3</td>
<td>0.62</td>
<td>0.60</td>
<td>0.54</td>
<td>0.03</td>
<td>0.23</td>
</tr>
<tr>
<td>n-6 to n-3 Ratio</td>
<td>4.74</td>
<td>5.41</td>
<td>6.37</td>
<td>0.16</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>
**Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response**

**Body Temperature After a LPS Challenge**

- **Peak temperature**
  - TRT: P = 0.14
  - Linear: P = 0.96
  - Quadratic: P = 0.05

- **Time to peak temperature**
  - TRT: P = 0.07
  - Linear: P = 0.08
  - Quadratic: P = 0.28
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Plasma Glucose and Insulin After a LPS Challenge

**Glucose, mg/dL**

- TRT: $P = 0.42$
- Time: $P < 0.001$
- TRT*Time: $P < 0.39$
- Linear: $P = 0.68$
- Quadratic: $P = 0.21$

**Insulin, ng/mL**

- TRT: $P = 0.66$
- Time: $P < 0.001$
- TRT*Time: $P = 0.24$
- Linear: $P = 0.44$
- Quadratic: $P = 0.66$
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Milk Somatic Cell Count After a LPS Challenge

![Graph showing milk somatic cell count over time relative to LPS infusion.]

- **R-4**, **R-5**, **R-6**: Different treatments.
- **Control Non Infused**.

- **TRT**: $P = 0.09$
- **Time**: $P < 0.001$
- **TRT*Time**: $P = 0.07$
- **Linear**: $P = 0.78$
- **Quadratic**: $P = 0.03$
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Neutrophils Phagocytosis and Oxidative Burst

**TRT**: $P = 0.88$

**Time**: $P < 0.07$

**TRT*Time**: $P = 0.14$

**Linear**: $P = 0.64$

**Quadratic**: $P = 0.85$
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Plasma Acute Phase Proteins After a LPS Challenge

Haptoglobin, Optical Density

Acid Soluble Protein, µg/mL

- TRT: P = 0.99
- Time: P < 0.001
- TRT*Time: P = 0.77
- Linear: P = 0.95
- Quadratic: P = 0.99

- TRT: P = 0.30
- Time: P < 0.001
- TRT*Time: P = 0.57
- Linear: P = 0.18
- Quad: P = 0.61
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Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response
Plasma Acute Phase Proteins After a LPS Challenge

Interleukin-6, pg/mL
- R4
- R5
- R6

Time relative to LPS infusion, h

Interferon-γ, pg/mL
- R4
- R5
- R6

Time relative to LPS infusion, h

TRT: P = 0.51
Time: P < 0.01
TRT*Time: P = 0.57
Linear: P = 0.04
Quadratic: P = 0.28

TRT: P = 0.36
Time: P < 0.001
TRT*Time: P = 0.93
Linear: P = 0.51
Quadratic: P = 0.17
Altering the FA profile of the diet fed to dairy cows by manipulating the n6 to n3 FA:

• Improved lactation performance;
  – Energetically, 1.3 kg of ECM could not be accounted for by the nutrient intake of cows when fed a diet in which EPA and DHA replaced linoleic acid
  – Efficiency of feed conversion into 3.5% FCM increased 5.6%

• Reducing the ratio of n6:n3 FA partially attenuated the acute inflammatory response to a LPS challenge

• R4 cows had the lowest SCC, haptoglobin, IL-6 and IFN-γ
HOT TOPIC

Effects of Altering the Omega-6 to Omega-3 Ratio on Lactation Performance & Immune Response

Questions & Answers

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