Nutrition Strategies for Efficient and Sustainable Production of Poultry Meat and Eggs

Craig Coon
University of Arkansas
NANP Nutrition Summit
April 10, 2019
National Academy of Sciences, Washington, D.C.
Broiler Feeding Strategies in U.S. Are Different Than in Other Countries
<table>
<thead>
<tr>
<th>Year</th>
<th>Av. Wt.</th>
<th>3.6-4.4</th>
<th>4.4-5.2</th>
<th>5.2-6.0</th>
<th>&gt;6.0</th>
<th>&gt;7.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>5.1</td>
<td>24.4</td>
<td>18.7</td>
<td>32.7</td>
<td>24.2</td>
<td>0</td>
</tr>
<tr>
<td>2005</td>
<td>5.5</td>
<td>24.2</td>
<td>5.7</td>
<td>30</td>
<td>26.8</td>
<td>13.3</td>
</tr>
<tr>
<td>2009</td>
<td>5.65</td>
<td>24</td>
<td>9.2</td>
<td>16</td>
<td>26</td>
<td>24.8</td>
</tr>
<tr>
<td>2015</td>
<td>6.23</td>
<td>15.93</td>
<td>7.37</td>
<td>8.05</td>
<td>30.52</td>
<td>38.12</td>
</tr>
<tr>
<td>2018</td>
<td>6.29</td>
<td>16.64</td>
<td>7.89</td>
<td>3.79</td>
<td>36.96</td>
<td>34.72</td>
</tr>
</tbody>
</table>
Broiler Market Trends

- High breast meat yielding broilers
- Increased bird size
- Shorter growth period (faster growth rate)
- Various markets
- Big bird programs - Large % of U.S. market

> 6 lb: 71.68% in 2018 and 23% in 2000

*71.7% of meat produced!
Boneless Breast Meat in the Market

- Boneless breast meat is the popular meat of choice among the consumers
  - Retail fresh, further processed, prepared foods, foodservice
  - Portioned breast meat common for foodservice, sourced from larger broilers
DAYS AND CALORIES TO 5.0 LB. LIVE WT.
U.S. BROILER INDUSTRY 1992 THROUGH 2018

Days to 5.0 lbs.
Calories per Lb./5.0 lb. Bird
% WOG YIELD
U.S. BROILER INDUSTRY 1988 THROUGH 2018

Plant Yield
BONELESS BREAST MEAT YIELD (% OF LIVE WT.)
U.S. BROILER INDUSTRY 1988 THROUGH 2018
% HATCHABILITY (ADJ. TO 65 WEEKS OF AGE)
U.S. BROILER BREEDER INDUSTRY 1988 THROUGH 2018
% BROILER LIVABILITY AND WHOLE BIRD FIELD CONDEMNATION
U.S. BROILER INDUSTRY 1988 THROUGH 2018
In 2034--2.3 kg BW broiler will improve Calorie Conversion by 15% from present --Currently Require 5500 kcal ME/kg live wt---Decrease 42.2 feed kcal/yr/kg BW--- Require 4867 kcal ME/kg BW in 15 yrs

In 2034..Broiler livability will be 96.85%.....5% improvement each decade

In 2034..Broiler boneless breast meat will increase to 26.2% of live wt.......increase 0.5% of live wt/yr
In 2034----2.3 kg BW at 28.75 days—reduce \(0.56\) d/yr

Benefits of selecting broilers for faster growth rate is improved feed efficiency

Sooner broilers get to desired market size, higher the percentage of feed consumed goes to lean mass instead of body maintenance

Feed conversion declines as broilers get older because more feed consumed goes to maintenance
PROGRESS IN BROILER SELECTION: BENEFITS, LIMITATIONS AS ASSESSED BY THE DIGESTIVE FUNCTION, AND CONSEQUENCE ON DIETARY LYSINE CONCENTRATIONS

XIV EUROPEAN POULTRY CONFERENCE, STAVANGER, NORWAY, JUNE 2014

Bernard Carré
INRA, France
A model for feed intake calculation, set from literature data (42 publications)

Model

Known values

- Age
- Body weight
- Daily growth
- Feed composition (requirement adjusted)

Calculated values

- Daily feed intake

Carré et al., 2014. 14th European Poultry Conference, Stavanger (Norway)
Measured daily feed intake (g) in Ross broilers*

Model calculated daily feed intake (g)

\[ n = 61 \]
\[ R^2 = 0.990 \]
\[ \text{RSD} = 5.6 \]

Delezie et al., 2012; Serrano et al., 2012; Hashemipour et al., 2013; van der Hoeven-Hangoor et al., 2013 and Kim et al., 2013

* Carré et al., 2014.
Growth curves associated with different age at slaughter (2.5 kg)

Body weight (kg)

Model computations

Calculated daily feed intake (g)

Model

Body weight (kg)

Carré et al., 2014.
Evolution of broilers

- Daily feed intake / Body weight
- Organ weights / Body weight

Opposite directions

Difficult challenge

Slow increase in the challenge

Carré et al., 2014.
14th European Poultry Conference, Stavanger (Norway)
Predicting FCR and Protein Efficiency

<table>
<thead>
<tr>
<th>2.5 kg slaughter day</th>
<th>FCR</th>
<th>Protein efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.98</td>
<td>0.607</td>
</tr>
<tr>
<td>22</td>
<td>1.05</td>
<td>0.604</td>
</tr>
<tr>
<td>24</td>
<td>1.13</td>
<td>0.608</td>
</tr>
<tr>
<td>26</td>
<td>1.20</td>
<td>0.606</td>
</tr>
<tr>
<td>28</td>
<td>1.27</td>
<td>0.606</td>
</tr>
<tr>
<td>30</td>
<td>1.35</td>
<td>0.607</td>
</tr>
<tr>
<td>32</td>
<td>1.41</td>
<td>0.604</td>
</tr>
<tr>
<td>34</td>
<td>1.48</td>
<td>0.602</td>
</tr>
<tr>
<td>56</td>
<td>2.22</td>
<td>0.540</td>
</tr>
</tbody>
</table>

Carre, 2014
## Predicting DFI and % Digestible Lysine

### DFI (g) = $aBW^j$ (kg)

<table>
<thead>
<tr>
<th>2.5 kg slaughter day</th>
<th>a</th>
<th>j</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>134</td>
<td>0.68</td>
</tr>
<tr>
<td>22</td>
<td>132</td>
<td>0.69</td>
</tr>
<tr>
<td>24</td>
<td>130</td>
<td>0.70</td>
</tr>
<tr>
<td>26</td>
<td>128</td>
<td>0.71</td>
</tr>
<tr>
<td>28</td>
<td>126</td>
<td>0.71</td>
</tr>
<tr>
<td>30</td>
<td>123</td>
<td>0.72</td>
</tr>
<tr>
<td>32</td>
<td>122</td>
<td>0.72</td>
</tr>
<tr>
<td>34</td>
<td>120</td>
<td>0.72</td>
</tr>
<tr>
<td>56</td>
<td>103</td>
<td>0.69</td>
</tr>
</tbody>
</table>

### Digestible lysine recommendations (feed %)

<table>
<thead>
<tr>
<th>2.5 kg slaughter day</th>
<th>Start.</th>
<th>Grow.</th>
<th>Finish.</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1.60</td>
<td>1.59</td>
<td>1.38</td>
</tr>
<tr>
<td>22</td>
<td>1.53</td>
<td>1.49</td>
<td>1.34</td>
</tr>
<tr>
<td>24</td>
<td>1.47</td>
<td>1.44</td>
<td>1.23</td>
</tr>
<tr>
<td>26</td>
<td>1.42</td>
<td>1.39</td>
<td>1.18</td>
</tr>
<tr>
<td>28</td>
<td>1.38</td>
<td>1.36</td>
<td>1.13</td>
</tr>
<tr>
<td>30</td>
<td>1.32</td>
<td>1.30</td>
<td>1.08</td>
</tr>
<tr>
<td>32</td>
<td>1.29</td>
<td>1.27</td>
<td>1.03</td>
</tr>
<tr>
<td>34</td>
<td>1.26</td>
<td>1.23</td>
<td>1.00</td>
</tr>
<tr>
<td>56</td>
<td>1.07</td>
<td>0.99</td>
<td>0.73</td>
</tr>
</tbody>
</table>

Carre, 2014
Model computations

Consequences of one day gained (from 34 to 20 days) in the rearing period for a 2.5 kg slaughter weight

Feed / Gain : $-0.034$ or $-2.7\%$

Protein gain / Protein intake : $+0\%$

Dig. Lysine feed concentration:
- (grower diet) $+0.26\,\text{g/kg}$ or $+2.0\%$
- (finisher diet) $+0.27\,\text{g/kg}$ or $+2.7\%$

Carré et al., 2014.
COMPARATIVE RESPONSE OF DIFFERENT BROILER GENOTYPES TO DIETARY NUTRIENT LEVELS

Franco Mussini
Dupont Inc.
# Jejunum length (49 days)

Table 10. Jejunum length and ratio to BW at 49 d

<table>
<thead>
<tr>
<th>Strain</th>
<th>Body weight(g)</th>
<th>Jejunum length (cm)</th>
<th>Jejunum (g BW/cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ross 308</td>
<td>3768.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>90.88&lt;sup&gt;a&lt;/sup&gt;</td>
<td>41.64&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ross 708</td>
<td>3642.78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>85.77&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>42.70&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ross TY</td>
<td>3732.78&lt;sup&gt;a&lt;/sup&gt;</td>
<td>81.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.09&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Heritage</td>
<td>1767.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>67.33&lt;sup&gt;c&lt;/sup&gt;</td>
<td>26.37&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>
Villus length (28 d)

Table 14. Villus morphometry by strain

<table>
<thead>
<tr>
<th>Strain</th>
<th>Villus length (µm)</th>
<th>Villus width (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>308</td>
<td>1574&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>231</td>
</tr>
<tr>
<td>708</td>
<td>1637&lt;sup&gt;a&lt;/sup&gt;</td>
<td>176</td>
</tr>
<tr>
<td>TY</td>
<td>1705&lt;sup&gt;a&lt;/sup&gt;</td>
<td>203</td>
</tr>
<tr>
<td>HER</td>
<td>1484&lt;sup&gt;b&lt;/sup&gt;</td>
<td>146</td>
</tr>
</tbody>
</table>

Prob > F: 0.0112 0.471
## Tibia diameter and breaking strength

Table 16. BW and tibia diameter and breaking strength

<table>
<thead>
<tr>
<th>Strain</th>
<th>BW (g)</th>
<th>Diameter (mm)</th>
<th>Breaking strength (Kg/mm)</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ross TY</td>
<td>2201.25$^a$</td>
<td>8.002$^b$</td>
<td>38.185$^a$</td>
<td>35 days</td>
</tr>
<tr>
<td>Heritage</td>
<td>1767.22$^b$</td>
<td>9.555$^a$</td>
<td>23.313$^b$</td>
<td>49 days</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>&lt;.0001</td>
<td>0.0041</td>
<td>0.0008</td>
<td></td>
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<tr>
<td>SEM</td>
<td>61.9</td>
<td>0.294</td>
<td>2.531</td>
<td></td>
</tr>
</tbody>
</table>
White Striping and Woody Breast in the Broiler Meat Industry

Casey M. Owens, Ph.D.
University of Arkansas
Breast Myopathies

- **Recent**: growth related myopathies
- **Myopathies show histological lesions**
  - Fiber degeneration, fibrosis, lipid infiltration, inflammatory cells, etc.
- **Mazzoni et al. (2015) reported that all breast from heavy broilers had histological lesions, but % of fibers affected varies**
  - >20% fibers show degeneration in severe cases
- **White striping and Woody Breast**

Kuttappan et al., 2013; Sihvo et al., 2014; Trocino et al., 2015; de Brot et al., 2016
Economic Losses

- Condemnation
  - trim, whole fillet, or carcass!
- Decreased yield
  - Drip loss, Cook loss, Marinade retention
- Decreased value (downgrades)
- Adding and training personnel for grading/sorting
- Lost business?

$200 million
USD, Annually, conservative

Kuttappan et al., 2016
Breast Myopathies/Meat Quality

Industry Concerns?

YES!

Why?
• Quality defect at high incidence
• Downgrades/Condemns
• Customer (restaurants) complaints
• Consumer awareness
• Economic losses
In the Media.....

MEAT+POULTRY

Mysterious myopathy

SPT. 27, 2016 - BY KIMBERLY CUNA

Check out the latest chicken diseases.

Yes, sadly, these are actually real diseases that affect the quality of chicken meat (people don't seem to care about the chickens themselves). All of these are caused by the Frankensteiian breeding practices used by the industry.

Source: Oatl@best.com
White Striations

• White striping is the occurrence of varying degrees of white striations

• Commonly seen on breast fillets and thighs

• An emerging tissue in broiler meat industry
  • Global markets
Incidence of SEVERE WS in Commercial Plants

- 35-40% with ~8.5+ lbs
- 10-20% with ~7 lbs

Multiple plants, strains
Increased lesions – H&E
 Increased fibrosis – Masson’s Trichrome
 Increased lipids – Oil Red O

Composition:
- Increased Fat
- Decreased Protein
- Increased protein breakdown
- Increased expression of proteolytic genes (Murf-1, Atrogin-1)

Kuttappan et al., 2013
Vignale et al., 2016
Wooden “Woody” Breast

Compression level

Normal

Woody

Blood vessel
Inflammation
Adipose cells
Muscle fiber splitting
Muscle fiber fragmentation
Degenerated/dying muscle fibers

Kuttappan et al., 2016
Incidence of MODERATE and SEVERE WB in Commercial Plants

2016-2017
Multiple plants, strains
High yielding strains > Standard yielding

- 20-35+% incidence
- ~8.5+ lbs

- 5-10% incidence
- ~7 lbs
How to Manage Woody Breast in Short Term: Live Production

• Nutritional modification
  • Recommendation: Reduced lysine in growout (12-24d)

✓ Reduced (15%) amino acids
✓ Reduced severity of WB
✓ No change in FCR
✓ Improved breast meat value when accounting for WB

Lee and Alvarado, 2017
Development of the ARK* NE system

University of Arkansas, Center of Excellence for Poultry Science, Fayetteville, Arkansas
Adapted from Farrell, 1974

**Gross Energy**
- Energy loss FAECES
- Energy loss URINE
- Heat Increment

**Apparently Digestible Energy**
- 77%

**Metabolizable Energy**
- 73%

**Net Energy**
- Net Energy Gain
- Net Energy Maintenance
- 53%

*Energy values are from Morris and Freeman, 1974*

100 %

* 4400 Kcal/Kg

3400 Kcal/Kg

3200 Kcal/Kg

2800 - 1800 Kcal/Kg
INTRODUCTION

• Utilizing a NE system will further enhance efficiency and profitability (Wu, et. al. 2018)
  – More accurate way to formulate to energy needs reducing over and under formulation

• Classic NE equations accounts for no information about type of body composition
  – Fat gain vs. protein gain
CLASSIC NE EQUATION:

$\text{NE (kcal/kg)} = \text{AME intake} - \text{HI}^*$

*HI=Heat Increment
ARK NE EQUATION*: 

\[
\text{NE (kcal/kg)} = \text{NEg} + \text{NEm}
\]

Body Composition \quad HP

*patent applied for by the University of Arkansas System, Division of Agriculture
Table 2. Comparison of Arkansas net energy value verse classic net energy value by line.

<table>
<thead>
<tr>
<th>Line</th>
<th>AME</th>
<th>Classic NE</th>
<th>Arkansas NE Equation</th>
<th>kcal Difference</th>
<th>Classic NE/ME</th>
<th>Arkansas Equation NE/ME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kcals</td>
<td>kcals/kg</td>
<td>kcals/kg</td>
<td>kcals/kg</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>A</td>
<td>3,137</td>
<td>2,460</td>
<td>3,498</td>
<td>1,038</td>
<td>78</td>
<td>111</td>
</tr>
<tr>
<td>B</td>
<td>3,137</td>
<td>2,379</td>
<td>3,325</td>
<td>946</td>
<td>75</td>
<td>105</td>
</tr>
</tbody>
</table>
### Table 3. Experiment 1 results comparison by temperature.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>AME</th>
<th>Classic NE</th>
<th>Arkansas NE Equation</th>
<th>kcal Difference</th>
<th>Classic NE/ME</th>
<th>Arkansas NE/ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cool</td>
<td>3,137</td>
<td>2,492</td>
<td>3,699&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,207</td>
<td>79</td>
<td>117</td>
</tr>
<tr>
<td>Hot</td>
<td>3,137</td>
<td>2,347</td>
<td>3,124&lt;sup&gt;b&lt;/sup&gt;</td>
<td>777</td>
<td>75</td>
<td>99</td>
</tr>
</tbody>
</table>

<sup>a</sup> p-value 0.0180
Change in body composition 22-42d.

Protein retention $p<0.0001$
Fat retention $p<0.0001$

Amino Acid Level | ME | Classic NE | Ark NE Equation
--- | --- | --- | ---
% | kcals | kcals/kg | kcals/kg
80 | 3,137 | 2,476 | 3,128
100 | 3,137 | 2,423 | 3,557
120 | 3,137 | 2,359 | 3,550

Correlation of protein gain and Heat Production

R² = 0.9778

Heat Production, kcals/day

PROTEIN GAIN, G

80AA  100AA  120AA

DIET

Heat Production, kcals/d/b

Body Protein gain, g
Correlation of fat gain and Heat Production

$R^2 = 0.9832$

Heat Production, kcals

FAT GAIN, G

DIET

2800 3030 3100

Mean(Body Fat Gain) HP kcal/d Linear ( HP kcal/d )
COMMERCIAL LAYERS

Dr. Neil O’Sullivan
Hy-Line Genetics
## Annualized Genetic Gain

<table>
<thead>
<tr>
<th>Trait</th>
<th>Hy-Line Brown</th>
<th>Hy-Line W36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age @ 50% Pr</td>
<td>0.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Livability in Grow</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Livability in Lay</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>HH Eggs</td>
<td>3.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Body Weight @ 18wk @ 32wk</td>
<td>25g</td>
<td>15g</td>
</tr>
<tr>
<td>@ 42wk</td>
<td>15g</td>
<td>10g</td>
</tr>
<tr>
<td>@ 42wk</td>
<td>5g</td>
<td>5g</td>
</tr>
<tr>
<td>Feed Conversion</td>
<td>1.3%</td>
<td>1.2%</td>
</tr>
<tr>
<td>Out of Nest Eggs</td>
<td>-6.7%</td>
<td>-0.2%</td>
</tr>
</tbody>
</table>
# Annualized Genetic Gain

<table>
<thead>
<tr>
<th>Trait</th>
<th>Hy-Line Brown</th>
<th>Hy-Line W36</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Weight - First</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ 26wk</td>
<td>0.45g</td>
<td>0.40g</td>
</tr>
<tr>
<td>@ 42wk</td>
<td>0.30g</td>
<td>0.35g</td>
</tr>
<tr>
<td>@ 60wk</td>
<td>0.10g</td>
<td>0.10g</td>
</tr>
<tr>
<td>Yolk Weight @ 26 Wk</td>
<td>0.00g</td>
<td>-0.01g</td>
</tr>
<tr>
<td>Shell Strength</td>
<td>0.31g</td>
<td>0.19g</td>
</tr>
<tr>
<td>Haugh Units</td>
<td>6g</td>
<td>5g</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Layer Nutrition and Management Changes

Single Cycle Production  Cage Free Production
Hy-Line will celebrate 100 years with our hens laying 550 eggs to 100 weeks of age.
Hy-Line will celebrate 100 years with our hens converting 1.15 kg feed into 1.0 kg eggs to 100 weeks.
Hy-Line will celebrate 100 years with our hens living at 97% to 100 weeks.
Digitalization of the Feed Industry

Report: Agriculture in Top 5 Most Automatable Industries, Above Retail

© OCTOBER 24, 2017  EMMA COSGROVE

Agriculture is the least digitized of all major industries, according to the McKinsey Global Institute’s Digitization Index. But a recent study by the same firm entitled “Human + Machine: A new era of automation in manufacturing,” looked at agriculture’s potential for automation and the results suggest that this has little to do with the fundamental tasks and activities that make up farming. The report set out to not only evaluate the
All nutrition boils down to the simple concept of Supply & Demand

More specifically:
Nutrient Supply and Nutrient Demand
Nutrient Variation is the Reality in Our Industry

Crop genetics / variety

Environment harvest

Sources of Nutrient Variation

Storage or transport

Processing
Soybean Meal Protein

Each line represents a major industry supplier of SBM and shows average protein levels over time

Crude Protein %

2.21% Spread, 4.88% Difference
CONCLUSIONS

- Fastest Way to Select for Feed Efficiency is through rate of gain
- In 15 years – Industry will be marketing 2.3 kg broiler in 28 days
- Projected 2.5 kg broiler at 20 days will have a 1:1 FCR—Will happen in 2048/2049 at current increase in gain
- NE is more efficient use of calories than ME and should reflect protein gain
- Future conflicts ahead between digestive function and meat yield
- Continued conflicts ahead with regard to meat quality—white striping and woodie breast—short term answer is slow down rate of gain
- Egg industry is on target to continue reducing feed intake, increase egg mass output and livability
- Egg industry is moving to single cycle production with less need to molt and also observing increased cage-free production
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