Pork Fat and Pork Fat Quality Measures - How does one implement a useful system?

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Meat Science Research Group

Presentation to the
RMC Reciprocation Session

June 19, 2012
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Three Reasons to Maintain Vigilance

1. Fat Quality measurement systems are still developing

2. Fat Quality is too variable

3. Fat Quality data management needs a useful framework
FAT QUALITY MEASUREMENT SYSTEMS ARE STILL DEVELOPING
Bacon is A Valuable Product

- Value to the consumer
- Value to the industry
- Value to the grower
Problems Caused by Poor Fat Quality in Bellies

- Reduction in number of “No. 1” slices
- Oily appearance of slices
- Increased rancidity development
- Reduced bacon palatability
- Difficulty in slicing
- “Tiger striping”
- Reduces bacon yields
- Reduces fresh belly exportability

1 J. Apple, 2010, 63rd RMC, Lubbock, TX
Fat Quality Measurement Systems

- Visual appraisal
- Finger-testing
- “Hand-Held”
- Iodine Value
- Fatty acids (ratios)
- Flop/bend tests
- Mechanical compression
- Puncture testing
- Others (imagination is the only hindrance)

1 J. Apple, 2010, 63rd RMC, Lubbock, TX
## Pros and Cons of Using Iodine Value

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective measurement</td>
<td>Labor and time intensive (high cost)</td>
</tr>
</tbody>
</table>
| Can identify firm vs. soft bellies/fat with a relatively high degree of reliability | Issues of variability in measurements  
- high standard deviations  
- analysis conducted using very small sample sizes |
| Can maintain trends in fat firmness over time | Inability to determine economics of lower IV’s  
- inconclusive data indicating lower IV bellies have higher slicing yields  
- difficulty in finding economic advantage for the appearance of firmer fat on cuts |
| Can determine variability in fat firmness among raw material suppliers | |

*N. Matthews (personal communication, March 6, 2008)*
Fat Quality Measurement...

Has stagnated for many reasons:

- Lack of clearly defined fat quality standards
- Lack of a clear path to deal with the variability in pork bellies
- High cost of methods to measure IV
- Lack of a clear path to implement a fat quality standard
- Lack of knowledge regarding the consequences of fat quality measurement standards
  - Both intended and unintended
  - Everyone has a stake in it
Fat Quality Study at OM

- Three rapid fat quality measures
  - Objective
    1. Bruker FTNIR (reflectance)
    2. Durometer
  - Subjective
    3. Fat Quality Score (FQS)
      - Based on a 5-point scale

- Bellies from multiple vendors

- Bellies from two different weight ranges
  - 10/12 pound
  - 12/14 pound

- Repeated three times

- OM Slice Yield
• FTNIR used reflectance mode, one reading per belly – this took ca. 15 to 30 seconds per reading. The base maintained 100 mm distance from surface to “window” of the FOP.
• Durometer value was read directly from the dial in dimensionless units. Higher values were obtained as firmness increased. One reading per belly.
• FQS value was subjectively assessed on a five-point scale on the fat side of each belly. One assessment per belly.
Location of Measurements

- **dorsal**
  - FTNIR & Durometer
  - Fat side up

- **ventral**
  - FSQ – fat side (over whole surface)

- **anterior**

- **posterior**

**FQS scale:**
- 1 = white, firm, smooth fat
- 3 = soft, spongy fat, fingerprints left
- 5 = soft, spongy fat, fingerprints, oily at cooler temps.
Differences in Fat Quality Measures by Vendor Establishment and Belly Weight Class

LS Means Plot

FTNIR LS Means

A B C D E F

10/12 12/14

Durometer value LS Means

A B C D E F

10/12 12/14

FOS-fat 2 LS Means

A B C D E F

10/12 12/14

OM Yield LS Means

Increasing Yield

A B C D E F

10/12 12/14
Correlations Among Direct Measures of Fat Quality (over all vendors)

### Overall all weight classes

<table>
<thead>
<tr>
<th></th>
<th>FTNIR Avg</th>
<th>Durometer avg</th>
<th>FQS-lean</th>
<th>FQS-fat</th>
<th>OM Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTNIR Avg</td>
<td>1.0000</td>
<td>-0.3747</td>
<td>-0.0149</td>
<td>0.0185</td>
<td>-0.2707</td>
</tr>
<tr>
<td>Durometer avg</td>
<td>-0.3747</td>
<td>1.0000</td>
<td>-0.6008</td>
<td>-0.0571</td>
<td>0.3595</td>
</tr>
<tr>
<td>FQS-lean</td>
<td>-0.0149</td>
<td>-0.6008</td>
<td>1.0000</td>
<td>0.9263</td>
<td>-0.2488</td>
</tr>
<tr>
<td>FQS-fat</td>
<td>0.0185</td>
<td>-0.5571</td>
<td>0.9263</td>
<td>1.0000</td>
<td>-0.3234</td>
</tr>
<tr>
<td>OM Yield</td>
<td>0.2107</td>
<td>0.3595</td>
<td>0.2458</td>
<td>-0.3234</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Comments:
- Data set contains 36 rows of data (averages of the 50 individual belly measurements taken).
- Six vendor establishments x two weight ranges x three reps

### 10/12 lbs.

<table>
<thead>
<tr>
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<th>FTNIR Avg</th>
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</tr>
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<tbody>
<tr>
<td>FTNIR Avg</td>
<td>1.0000</td>
<td>-0.1448</td>
<td>-0.2622</td>
<td>-0.1949</td>
<td>-0.2390</td>
</tr>
<tr>
<td>Durometer avg</td>
<td>-0.1448</td>
<td>1.0000</td>
<td>-0.5165</td>
<td>-0.5329</td>
<td>0.3149</td>
</tr>
<tr>
<td>FQS-lean</td>
<td>-0.2622</td>
<td>-0.5165</td>
<td>1.0000</td>
<td>0.8743</td>
<td>0.1720</td>
</tr>
<tr>
<td>FQS-fat</td>
<td>-0.1949</td>
<td>-0.5329</td>
<td>0.8743</td>
<td>1.0000</td>
<td>-0.0504</td>
</tr>
<tr>
<td>OM Yield</td>
<td>0.2390</td>
<td>0.3149</td>
<td>0.1720</td>
<td>-0.0504</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

### 12/14 lbs.

<table>
<thead>
<tr>
<th></th>
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<th>FQS-lean</th>
<th>FQS-fat</th>
<th>OM Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTNIR Avg</td>
<td>1.0000</td>
<td>-0.4981</td>
<td>0.1938</td>
<td>0.2009</td>
<td>-0.2484</td>
</tr>
<tr>
<td>Durometer avg</td>
<td>-0.4981</td>
<td>1.0000</td>
<td>-0.6891</td>
<td>-0.6036</td>
<td>0.4982</td>
</tr>
<tr>
<td>FQS-lean</td>
<td>0.1938</td>
<td>-0.6891</td>
<td>1.0000</td>
<td>0.9501</td>
<td>-0.6001</td>
</tr>
<tr>
<td>FQS-fat</td>
<td>0.2009</td>
<td>-0.6036</td>
<td>0.9501</td>
<td>1.0000</td>
<td>-0.5942</td>
</tr>
<tr>
<td>OM Yield</td>
<td>-0.2484</td>
<td>0.4982</td>
<td>-0.6001</td>
<td>-0.5942</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

P<0.01
P<0.05
Ranking Vendor Establishment by Fat Quality Measures for 12/14 Pound Bellies

<table>
<thead>
<tr>
<th>FTNIR IV</th>
<th>Durometer</th>
<th>FQS-Fat</th>
<th>OM Slice Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>C</td>
<td>D</td>
<td>C</td>
</tr>
<tr>
<td>E</td>
<td>D</td>
<td>E</td>
<td>D</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td>B</td>
<td>E</td>
</tr>
<tr>
<td>F</td>
<td>F</td>
<td>A</td>
<td>F</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>F</td>
<td>A</td>
</tr>
</tbody>
</table>

Comment: In 12/14 lb. bellies, the top ranked vendor establishment agreed with the highest ranked OM slice yield. All fat measures ranked the same two vendor establishments (F and A) with the lowest OM slice yields.
Summary

• Fat quality measures:
  – Differentiated bellies between six vendor establishments
  – Differentiated bellies from two weight classifications
  – Were significantly (P<0.05) correlated with bacon slicing data in heavier bellies
  – Predicted IV from the Bruker FTNIR was not associated with slice yield (P>0.05)
    • Surface effects may have influenced the readings
    • Other factors affecting slice yield were not measured by the FTNIR
FAT QUALITY DATA IS TOO VARIABLE

How does one handle the variability in the data?
Scatter plots of Iodine Value by different Fat Quality measures

- C18:2n6: \( r = 0.98 \)
- Sat:Unsat: \( r = -0.88 \)
- TAXT2 firmness (g): \( r = -0.63 \)
- Adj slice yld: \( r = -0.4 \)
Slice Yield Risks

OM Slice Yield vs. IV

| Iodine Value (from fatty acid profile) | Zone of decreasing risk of poor yield | Zone of increasing risk of poor yield |

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Associations

Factor 1

Perfect knowledge
+
Precise measurement

with

Factor 2

Perfect knowledge
+
Precise measurement

Higher R^2

Scientific bliss
Associations

Factor 1

- Imperfect knowledge
  + Imprecise measurement

with

Factor 2

- Imperfect knowledge
  + Imprecise measurement

Lower $R^2$

*Scientific angst*

But what if there is another or are other things that influence the factors?

- Other factors?
- Co-linearity?
- Curvilinear rather than linear?
Errors Associated with Inappropriate Interpretations of Messy Data

- Place no weight on the results due to the scatter and low $R^2$
  - Over emphasizing the error and uncertainty
  - May miss important associations

- Place too much weight on the results
  - Under emphasizing the error and uncertainty
  - Over look potential “causes” of the associations
  - Results in too stringent an application
Positives for Correctly Interpreting the Data

- Knowledge of a “true” association
  - Can lead to some conclusions about the factors
- Direction on how to improve measurement precision
  - May require a better measurement system
- Direction for future research for the current factors and for other factors that may be associated
DEVELOPING A USEFUL FAT QUALITY MEASUREMENT FRAMEWORK
Requirement of a Meat Quality Measuring System

- Objective
- Have amenable accuracy
- Be reproducible
- Not operator dependent
- Unquestionable results
- High correlation with performance in finished product
- Rapid
- Simple to use
- Cost effective
Consider Using Population Statistics rather than Direct Measures from the Quality Measures

Instead of using the mean values to correlate with OM slice yield, let’s try looking at the proportion of the bellies from each vendor that exceed certain index values:

- IV>74*
- Durometer values<50*
- FQS scores >3*

*values obtained from previous OM research
Population Data Examples

Vendor A 10/12 lbs.

Vendor B 10/12 lbs.

Comments:
- This attempts to estimate the number of problem bellies that are being supplied by the various vendor establishments and weight ranges.
- In this example, vendor A (10/12 lb.) will provide fewer problem bellies (IV>74) than bellies provided by B (based on a 50 sample test from each vendor).
- Consequently, one would expect a higher OM slice yield from B than from A.
### Correlations Using Population Data by Weight Class

#### Over all

<table>
<thead>
<tr>
<th></th>
<th>IV&gt;74</th>
<th>Duro&lt;50</th>
<th>FQS&gt;3</th>
<th>OM Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV&gt;74</td>
<td>1.0000</td>
<td>0.5262</td>
<td>0.3176</td>
<td>-0.2064</td>
</tr>
<tr>
<td>Duro&lt;50</td>
<td>0.5262</td>
<td>1.0000</td>
<td>0.6019</td>
<td>-0.4043</td>
</tr>
<tr>
<td>FQS&gt;3</td>
<td>0.3176</td>
<td>0.6019</td>
<td>1.0000</td>
<td>-0.4209</td>
</tr>
<tr>
<td>OM Yield</td>
<td>-0.2064</td>
<td>-0.4043</td>
<td>-0.4209</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

#### 10/12 lbs.

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<th>FQS&gt;3</th>
<th>OM Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV&gt;74</td>
<td>1.0000</td>
<td>0.0681</td>
<td>0.0698</td>
<td>-0.1270</td>
</tr>
<tr>
<td>Duro&lt;50</td>
<td>0.0681</td>
<td>1.0000</td>
<td>0.5813</td>
<td>-0.3815</td>
</tr>
<tr>
<td>FQS&gt;3</td>
<td>0.0698</td>
<td>0.5813</td>
<td>1.0000</td>
<td>-0.1365</td>
</tr>
<tr>
<td>OM Yield</td>
<td>-0.1270</td>
<td>-0.3815</td>
<td>-0.1365</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

#### 12/14 lbs.

<table>
<thead>
<tr>
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<th>Duro&lt;50</th>
<th>FQS&gt;3</th>
<th>OM Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV&gt;74</td>
<td>1.0000</td>
<td>0.7388</td>
<td>0.5167</td>
<td>-0.3559</td>
</tr>
<tr>
<td>Duro&lt;50</td>
<td>0.7388</td>
<td>1.0000</td>
<td>0.6544</td>
<td>-0.5250</td>
</tr>
<tr>
<td>FQS&gt;3</td>
<td>0.5167</td>
<td>0.6544</td>
<td>1.0000</td>
<td>-0.7452</td>
</tr>
<tr>
<td>OM Yield</td>
<td>0.3559</td>
<td>0.5250</td>
<td>0.7452</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

*P<0.05*  
*P<0.01*
Population Factor Performance

\[ R^2 = 0.04 \]
\[ \text{RMSE} = 0.05 \]
\[ n=36 \]

\[ R^2 = 0.14 \]
\[ \text{RMSE} = 0.05 \]
\[ n=36 \]

\[ R^2 = 0.15 \]
\[ \text{RMSE} = 0.05 \]
\[ n=36 \]

Note that higher proportions of soft bellies have lower slice yields.
Using direct measures, n=36 (6 vendor establishments; two weight ranges; repeated 3 times)

<table>
<thead>
<tr>
<th># of parameters in the model</th>
<th>Factors</th>
<th>$R^2$</th>
<th>Root mean square error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Durometer</td>
<td>0.13</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>Durometer FQS-Fat</td>
<td>0.15</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>Durometer FQS—fat FTNIR IV</td>
<td>0.17</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>Durometer FQS—fat FTNIR IV Belly wt.</td>
<td>0.17</td>
<td>0.05</td>
</tr>
</tbody>
</table>

$^1$ Models indicated are the best models for each number of parameters in the model. They were derived using all subsets regression in JMP.
Impact Using Population-Based Measures

Using direct measures, n=36 (6 vendor establishments; two weight ranges; repeated 3 times)

<table>
<thead>
<tr>
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<th>$R^2$</th>
<th>Root mean square error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FQS&gt;3</td>
<td>0.18</td>
<td>0.05</td>
</tr>
<tr>
<td>2</td>
<td>FSQ&gt;3, Durometer&lt;50</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td>3</td>
<td>FQS&gt;3, Durometer&lt;50, Belly Wt.</td>
<td>0.21</td>
<td>0.05</td>
</tr>
<tr>
<td>4</td>
<td>FQS&gt;3, Durometer&lt;50, Belly wt., LV&gt;74</td>
<td>0.21</td>
<td>0.05</td>
</tr>
</tbody>
</table>

1 Models indicated are the best models for each number of parameters in the model. They were derived using all subsets regression in JMP.
Comparison of Fat Quality Measures

<table>
<thead>
<tr>
<th>FTNIR IV</th>
<th>Durometer</th>
<th>FQS</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Objective</td>
<td>• Simple, objective, and easy to use</td>
<td>• Subjective and subject to the training and experience of the grader</td>
</tr>
<tr>
<td>• Results are in the right ranges</td>
<td>• Directly measures firmness of belly fat; gives no information as to why the fat is softer</td>
<td>• Based on visual and physical characteristics of in situ pork fat</td>
</tr>
<tr>
<td>• Readings seem to be affected by surface effects</td>
<td>• Durometer values were correlated (P&lt;0.05) with OM slice yield especially in the 12/14 lb. belly weight class.</td>
<td>• FQS-fat scores were correlated P&lt;0.05) with OM slice yield in the 12/14 lb. belly weight class</td>
</tr>
<tr>
<td>• Easy to use</td>
<td>• Durometer&lt;50 was also correlated with OM slice yield for the 12/14 lb. weight belly class</td>
<td>• FQS-fat&gt;3 scores were highly correlated (P&lt;0.01) with OM slice yield</td>
</tr>
<tr>
<td>• Can be incorporated into any computerized grading scheme</td>
<td>• Calibration seems adequate, but future improvements may improve precision</td>
<td>• Expensive to purchase ($90,000)*</td>
</tr>
<tr>
<td>• Calibration seems adequate, but future improvements may improve precision</td>
<td>• Gives indirect measure of fat softness</td>
<td>• Relatively inexpensive ($800)</td>
</tr>
<tr>
<td>• IV values measures only fatty acid composition – this is associated with firmness</td>
<td>• IV values measures only fatty acid composition – this is associated with firmness</td>
<td>• No cost</td>
</tr>
<tr>
<td>• FTNIR IV was usually not correlated (P&gt;0.05) with OM slicing yields in this test</td>
<td>• Durometer values were correlated (P&lt;0.05) with OM slice yield especially in the 12/14 lb. belly weight class.</td>
<td></td>
</tr>
</tbody>
</table>

*Comment: One of the reasons for slow progress measuring fat quality is the expense of GC fatty acid analysis for IV. Commercially, this costs ca. $100/sample. Had we used commercial analyses, we would have spent $180,000 – double the cost of the FTNIR.
Conceptual Model of Factors Affecting Slice Yield

Slice Yield
Conceptual Model of Factors Affecting Slice Yield

Moisture varies with leanness

- Durometer
- Moisture
- Fat:lean ratio
- Fat
- Slice Yield
- Belly wt.
- Dimension
- R² = 0.17 to 0.21

- IV value
- FTNIR
- FQS

Husbandry/genetics/pig factors
Conceptual Model of Factors Affecting Slice Yield

- **Moisture**
  - Fat
  - Fat:lean ratio
  - R² = 0.17 to 0.21

- **Firmness**
- **Fat**
- **Belly wt.**
- **Dimension**

- **IV value**
- **FTNIR**
- **FQS**

- **Belly wt.**

- **Slice Parameters**
  - Grading
  - Workmanship
  - Slicer set up
  - Bacon pressing

- **Combing**

- **Manufacturing factors**
  - Manage these

- **Husbandry/genetics/pig factors**

- **Slice Yield**

- **Durometer**

Moisture varies with leanness

June 19, 2012

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Conceptual Model of Factors Affecting Slice Yield

Comments:
- Measuring only the fat neglects the other factors that can affect bacon slicing performance.
- These other measures can be just as impactful as the fat quality and need to be closely managed.
National Pork Board Work

- Evaluation of fat quality and its relationship to meat and eating quality traits of pork
- Improving carcass fat quality by manipulating the amount and timing of feeding dietary fats with different iodine values
- Determining Pork Fat Quality as Measured by Three Methods within an Industry Standard Marketing Plan for Pigs Fed 20% DDGS
- Influence of commercial deep chilling processes on early postmortem events in muscle that affect ultimate fresh pork tenderness and processing quality

1 Steve Larson, National Pork Board, personal communication
INDUSTRY FEEDBACK LOOP
WE ARE ALL IN THIS TOGETHER

Grower  Packer  Processor  Consumer