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

Dennis Seman
Associate Principal Scientist
Meat Science Research Group

Presentation to the
RMC Reciprocation Session

June 19, 2012

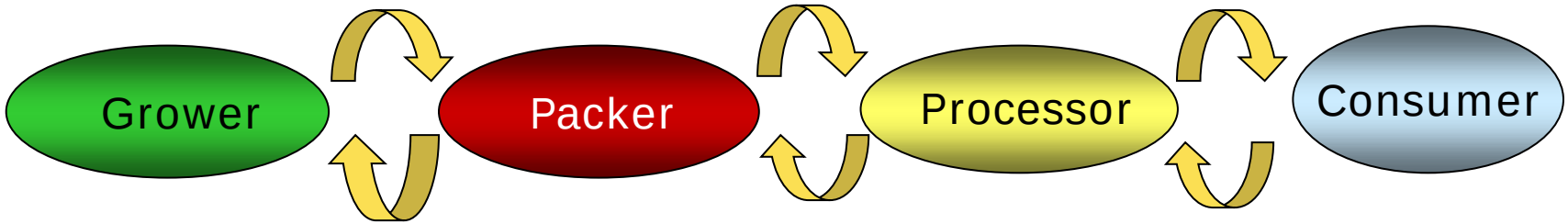
Three Reasons to Maintain Vigilance

1. Fat Quality measurement systems are still developing
2. Fat Quality is too variable
3. Fat Quality data management needs a useful framework

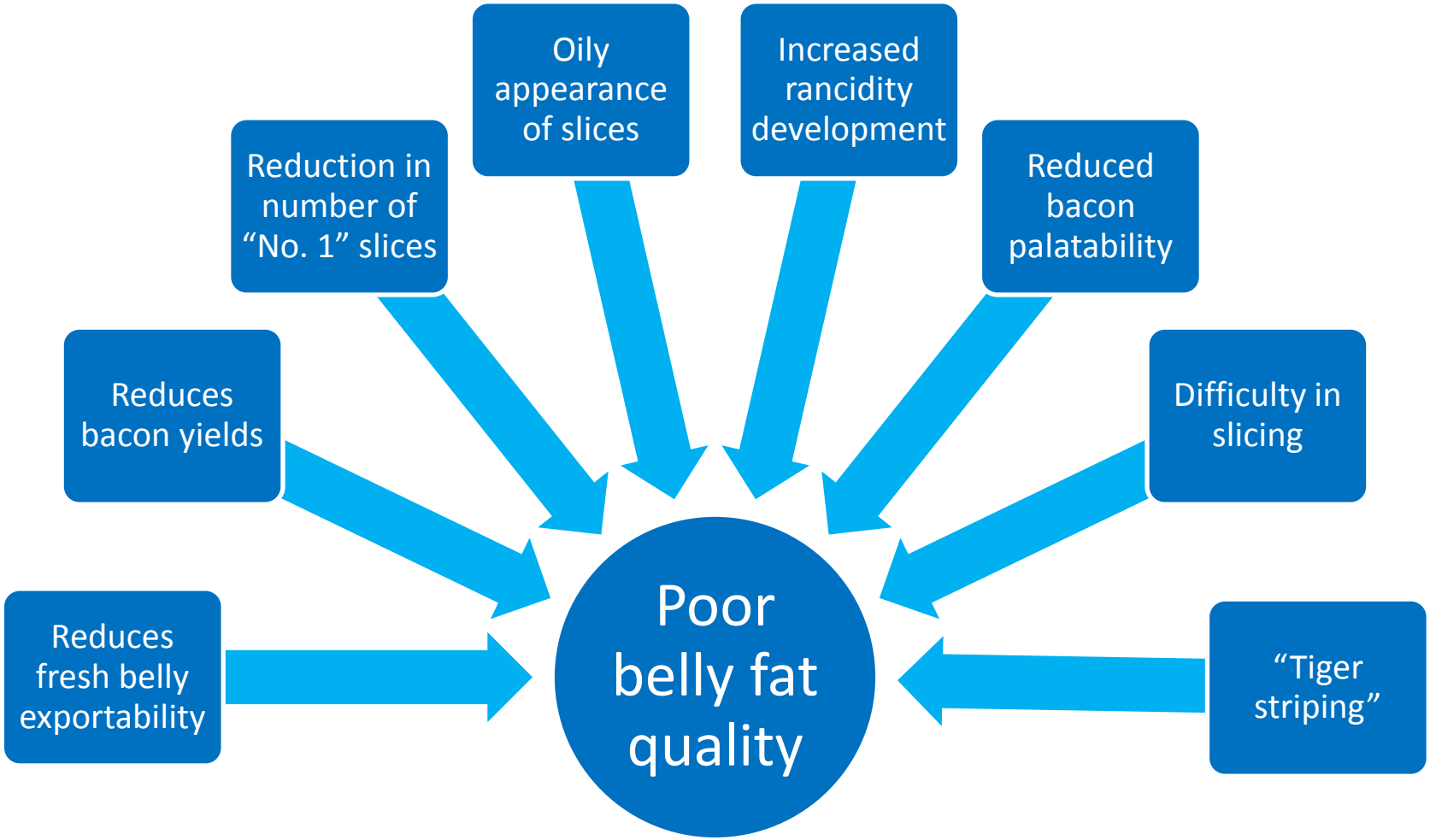
FAT QUALITY MEASUREMENT SYSTEMS ARE STILL DEVELOPING

Bacon is A Valuable Product

- Value to the consumer
- Value to the industry
- Value to the grower

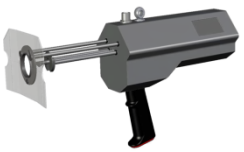


Problems Caused by Poor Fat Quality in Bellies[1]

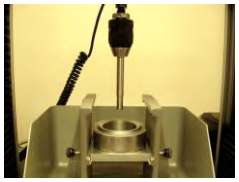


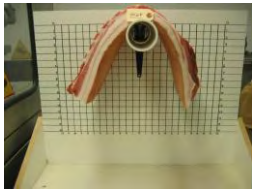
[1] J. Apple, 2010, 63rd RMC, Lubbock, TX

Fat Quality Measurement Systems[1]



- 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

Pros	Cons
Objective measurement	Labor and time intensive (high cost)
Can identify firm vs. soft bellies/fat with a relatively high degree of reliability	<u>Issues of variability in measurements</u> ▪high standard deviations ▪analysis conducted using very small sample sizes
Can maintain trends in fat firmness over time	<u>Inability to determine economics of lower IV's</u> ▪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)

kraft foods

Fat Quality Measurement . . .

Has stagnated for many reasons:

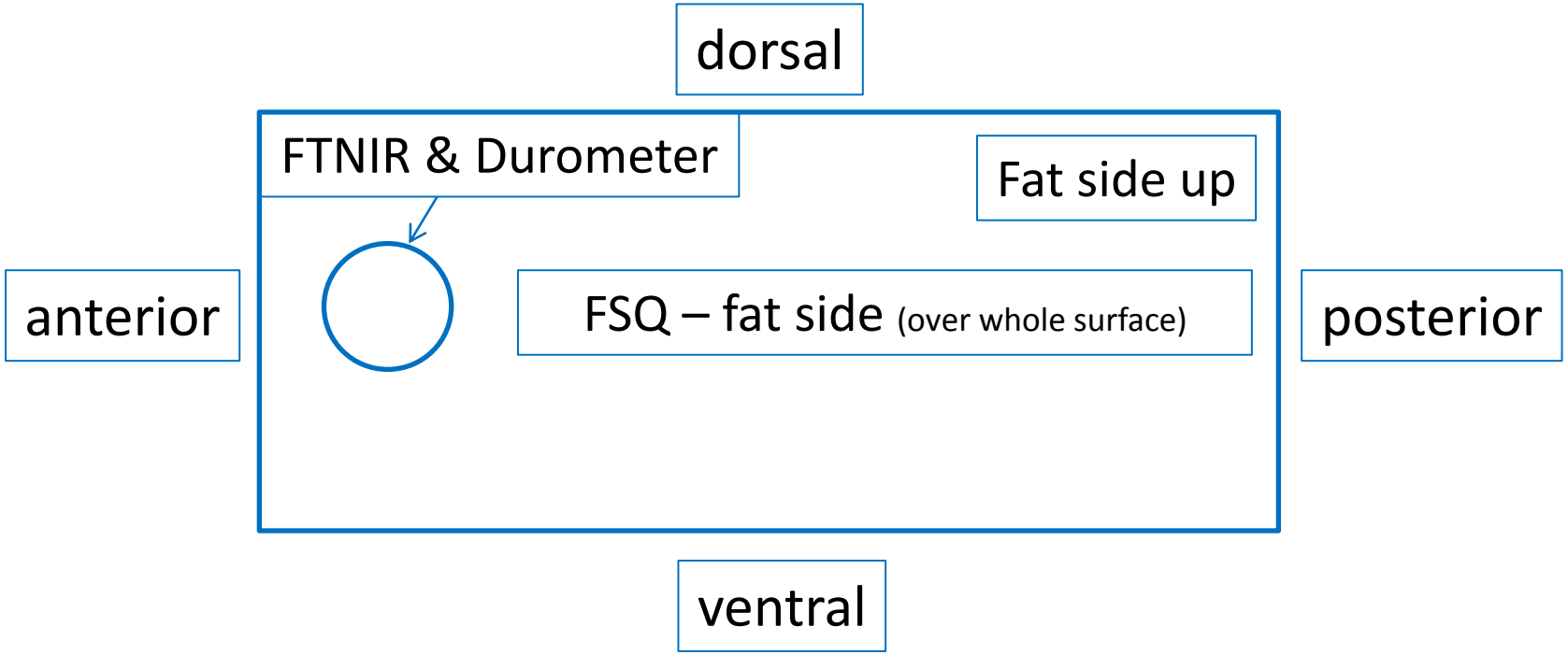
- Lack of clearly defined fat quality standards
- Lack of a clear path to deal with the variability in pork bellies
- High cost of methods to measure IV
- Lack of a clear path to implement a fat quality standard
- Lack of knowledge regarding the consequences of fat quality measurement standards
  - Both 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

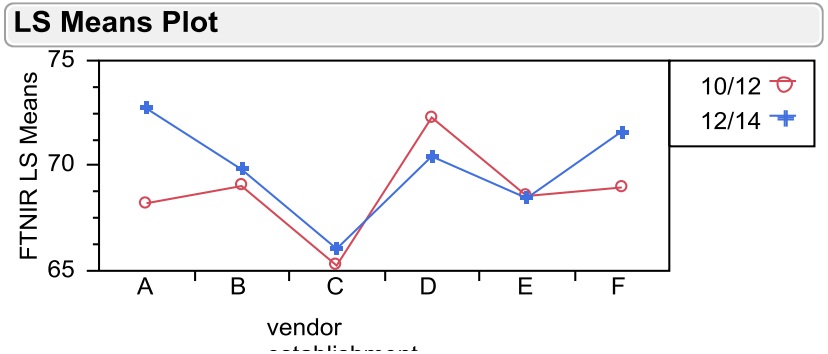
- FTNIR used reflectance mode, one reading per belly – this took ca. 15 to 30 seconds per reading. The base maintained 100 mm distance from surface to “window” of the FOP.
- Durometer value was read directly from the dial in dimensionless units. Higher values were obtained as firmness increased. One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

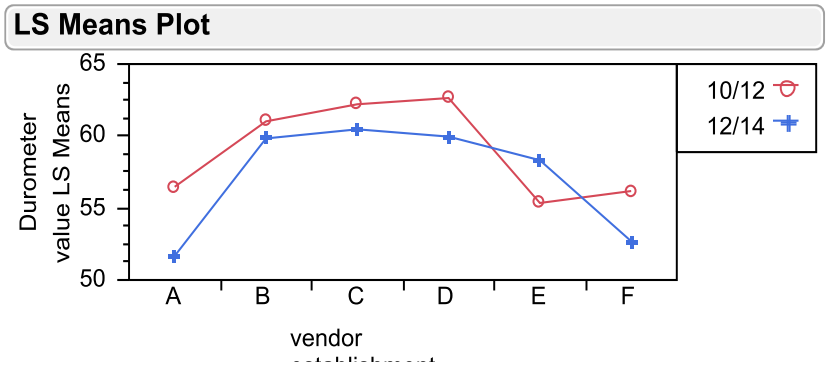
Location of Measurements

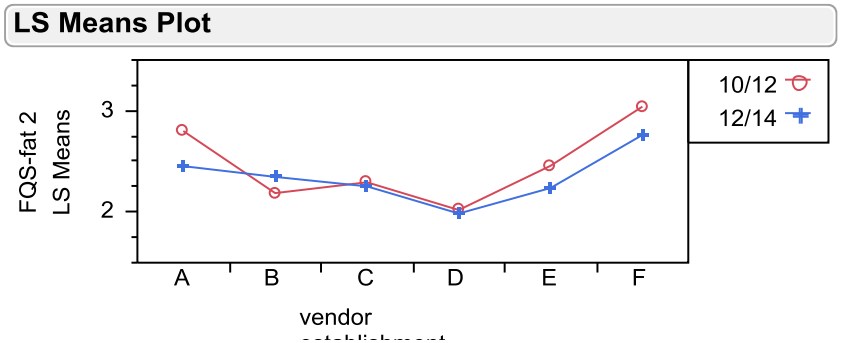


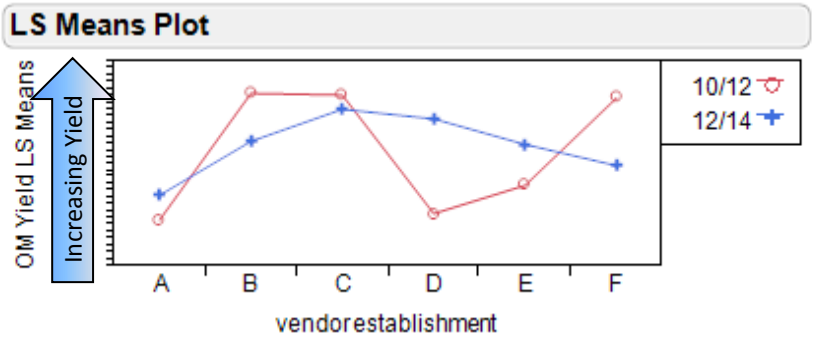
FQS scale: 1= white, firm, smooth fat
3= soft, spongy fat, fingerprints left
5= soft, spongy fat, fingerprints, oily at cooler temps.

Differences in Fat Quality Measures by Vendor Establishment and Belly Weight Class









Correlations Among Direct Measures of Fat Quality (over all vendors)

Overall all weight classes

Correlations

	FTNIR Avg	Durometer avg	FQS-lean	FQS-fat	OM Yield
FTNIR Avg	1.0000	-0.3747	-0.0149	0.0185	-0.2107
Durometer avg	-0.3747	1.0000	-0.6008	-0.5571	0.3595
FQS-lean	-0.0149	-0.6008	1.0000	0.9263	-0.2468
FQS-fat	0.0185	-0.5571	0.9263	1.0000	-0.3234
OM Yield	0.2107	0.3595	-0.2468	-0.3234	1.0000

10/12 lbs.

Correlations

	FTNIR Avg	Durometer avg	FQS-lean	FQS-fat	OM Yield
FTNIR Avg	1.0000	-0.1448	-0.2622	-0.1949	-0.2390
Durometer avg	-0.1448	1.0000	-0.5165	-0.5329	0.3149
FQS-lean	-0.2622	-0.5165	1.0000	0.8743	0.1720
FQS-fat	-0.1949	-0.5329	0.8743	1.0000	-0.0504
OM Yield	-0.2390	0.3149	0.1720	-0.0504	1.0000

12/14 lbs.

Correlations

	FTNIR Avg	Durometer avg	FQS-lean	FQS-fat	OM Yield
FTNIR Avg	1.0000	-0.4981	0.1938	0.2009	-0.2484
Durometer avg	-0.4981	1.0000	-0.6891	-0.6036	0.4982
FQS-lean	0.1938	-0.6891	1.0000	0.9501	-0.6001
FQS-fat	0.2009	-0.6036	0.9501	1.0000	-0.5942
OM Yield	-0.2484	0.4982	-0.6001	-0.5942	1.0000

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

P<0.01

P<0.05

kraft foods

Ranking Vendor Establishment by Fat Quality Measures for 12/14 Pound Bellies

Increasing Firmness
Decreasing unsaturation

FTNIR IV	Duro-meter	FQS-Fat	OM Slice Yield
C	C	D	C
E	D	E	D
B	B	C	B
D	E	B	E
F	F	A	F
A	A	F	A

Increasing Yield

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.

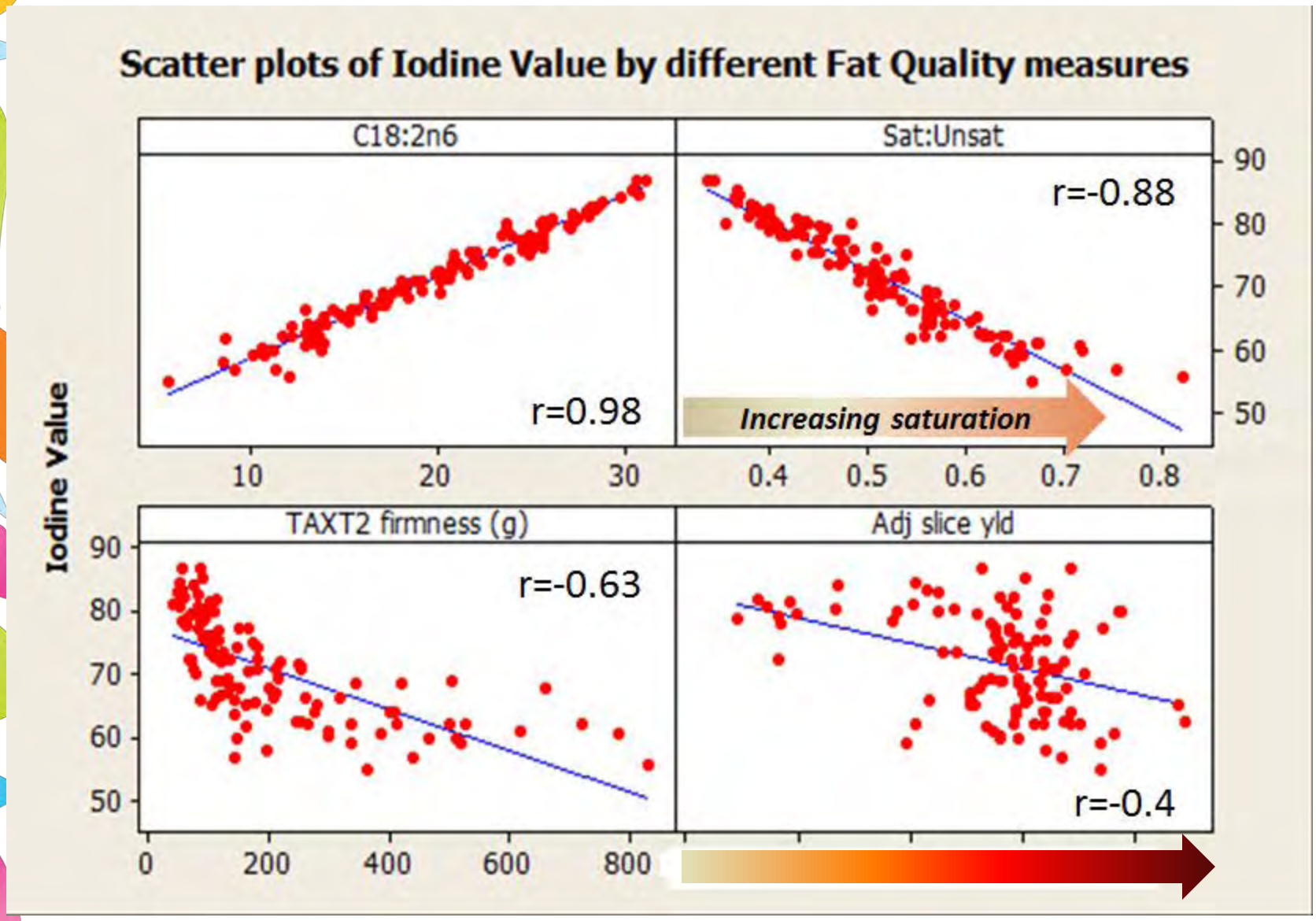
kraft foods

Summary

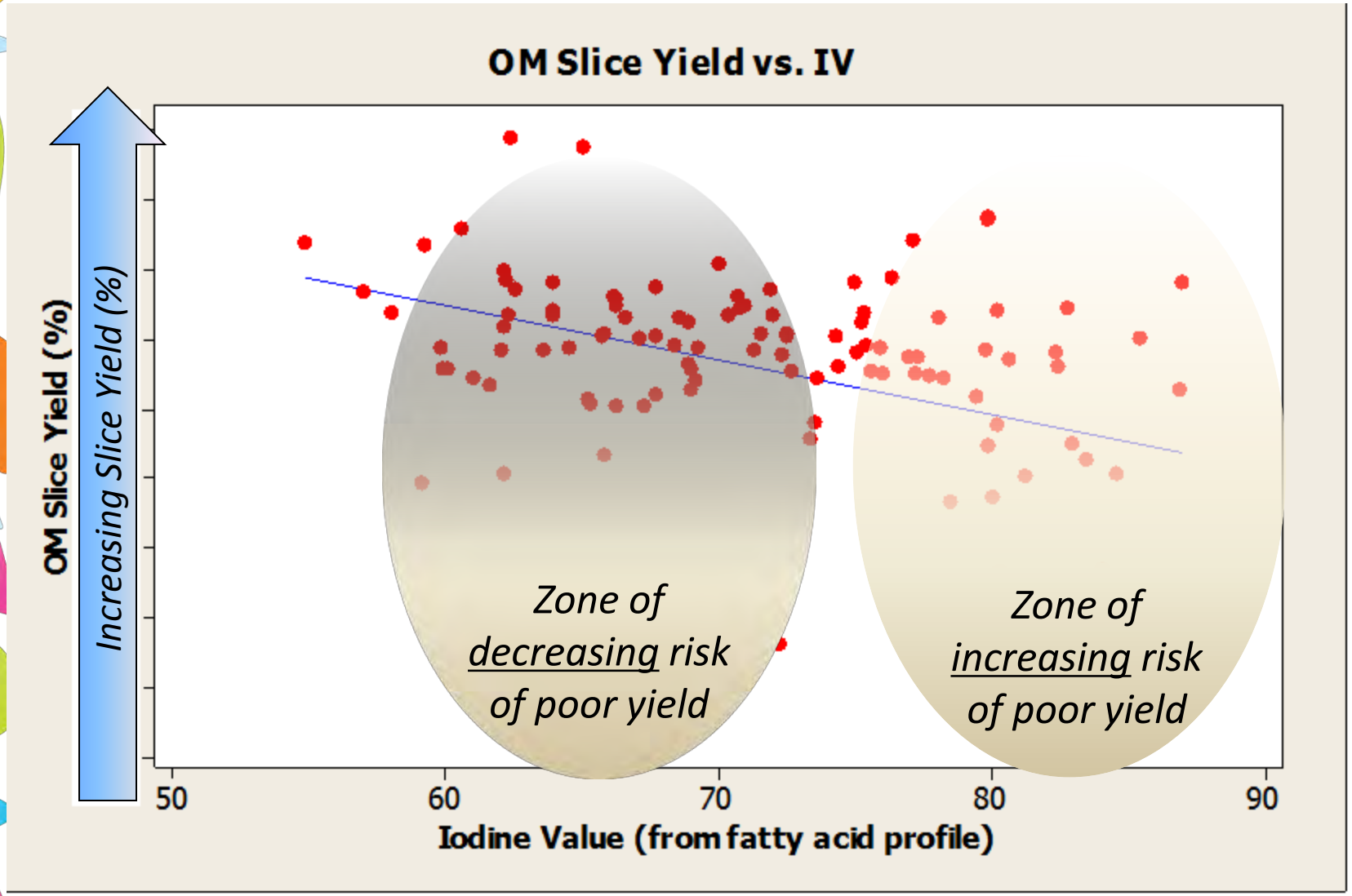
- Fat quality measures:
  - Differentiated bellies between six vendor establishments
  - Differentiated bellies from two weight classifications
  - Were significantly ($P<0.05$) correlated with bacon slicing data in heavier bellies
  - Predicted IV from the Bruker FTNIR was not associated with slice 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?



Slice Yield Risks



Associations

Factor 1

Perfect knowledge

+

Precise measurement

with

Factor 2

Perfect knowledge

+

Precise measurement

Higher R^2

Scientific bliss

Associations

Factor 1		Factor 2		
Imperfect knowledge + Imprecise measurement	with	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

kraft foods

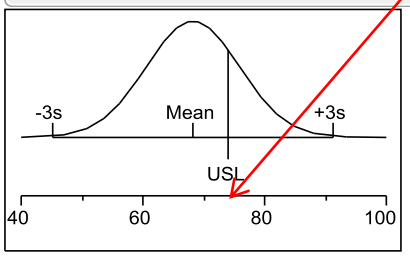
Population Data Examples

Vendor A 10/12 lbs.

Capability Analysis

Specification	Value	Portion	% Actual
Lower Spec Limit	.	Below LSL	.
Spec Target	.	Above USL	24.0000
Upper Spec Limit	74	Total Outside	24.0000

Long Term Sigma



Sigma =

Capability	Index	Lower CI	Upper CI
CP	.	.	.
CPK	0.251	0.190	0.311
CPM	.	.	.
CPL	.	.	.
CPU	0.251	0.190	0.311

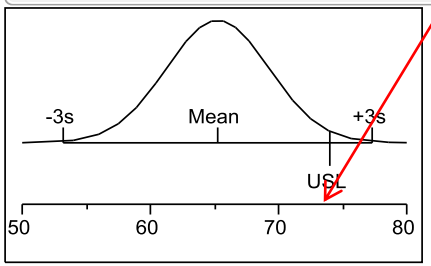
Portion	Percent	PPM	Sigma Quality
Below LSL	.	.	.
Above USL	22.5678	225677.70	2.253
Total Outside	22.5678	225677.70	2.253

Vendor B 10/12 lbs.

Capability Analysis

Specification	Value	Portion	% Actual
Lower Spec Limit	.	Below LSL	.
Spec Target	.	Above USL	2.0000
Upper Spec Limit	74	Total Outside	2.0000

Long Term Sigma



Sigma =

Capability	Index	Lower CI	Upper CI
CP	.	.	.
CPK	0.726	0.627	0.824
CPM	.	.	.
CPL	.	.	.
CPU	0.726	0.627	0.824

Portion	Percent	PPM	Sigma Quality
Below LSL	.	.	.
Above USL	1.4716	14716.332	3.678
Total Outside	1.4716	14716.332	3.678

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

Correlations

	IV>74	Duro<50	FQS>3	OM Yield
IV>74	1.0000	0.5262	0.3176	-0.2064
Duro<50	0.5262	1.0000	0.6019	-0.4043
FQS>3	0.3176	0.6019	1.0000	-0.4209
OM Yield	-0.2064	-0.4043	-0.4209	1.0000

10/12 lbs.

Correlations

	IV>74	Duro<50	FQS>3	OM Yield
IV>74	1.0000	0.0681	0.0698	-0.1270
Duro<50	0.0681	1.0000	0.5813	-0.3815
FQS>3	0.0698	0.5813	1.0000	-0.1365
OM Yield	-0.1270	-0.3815	-0.1365	1.0000

12/14 lbs.

Correlations

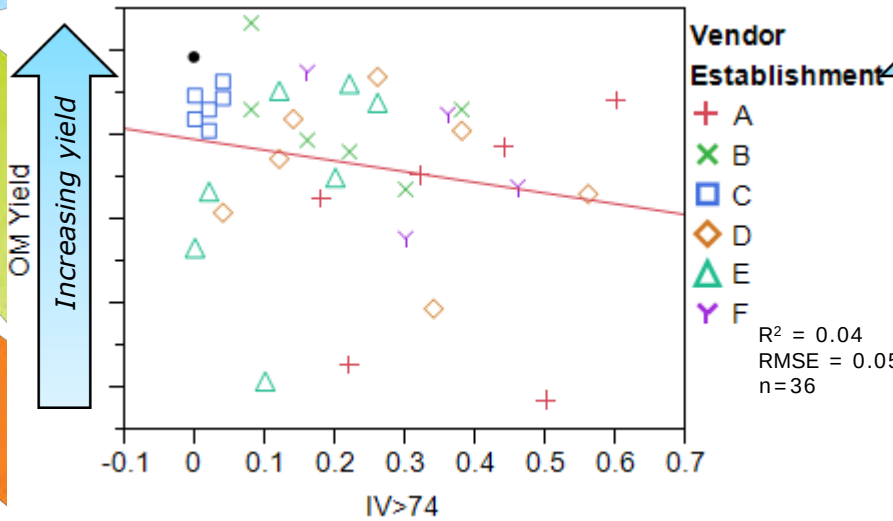
	IV>74	Duro<50	FQS>3	OM Yield
IV>74	1.0000	0.7388	0.5167	-0.3559
Duro<50	0.7388	1.0000	0.6544	-0.5250
FQS>3	0.5167	0.6544	1.0000	-0.7452
OM Yield	-0.3559	-0.5250	-0.7452	1.0000

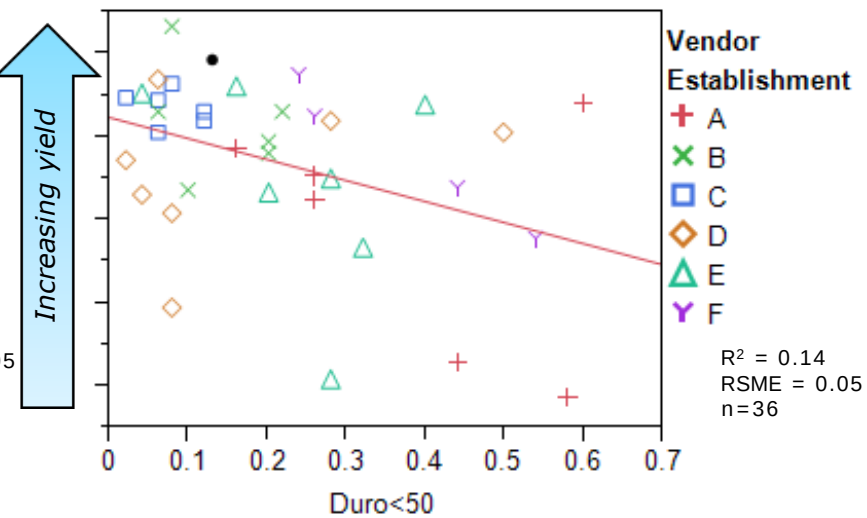
P<0.05

P<0.01

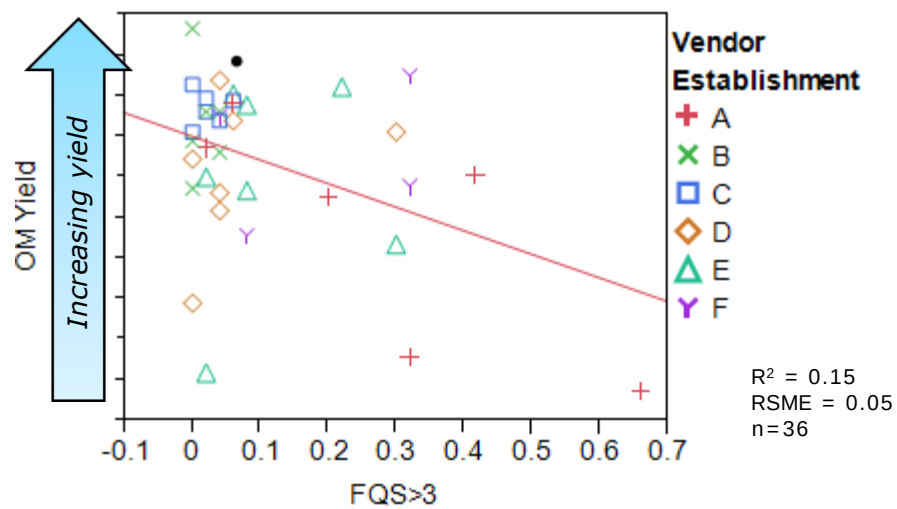
kraft foods

Population Factor Performance





Note that higher proportions of soft bellies have lower slice yields



Impact of Adding All Fat Quality Measures to Predict OM Slice Yield – Direct Measures Only[1]

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

# of parameters in the model	Factors	R^2	Root mean square error
1	Durometer	0.13	0.05
2	Durometer FQS-Fat	0.15	0.05
3	Durometer FQS—fat FTNIR IV	0.17	0.05
4	Durometer FQS—fat FTNIR IV Belly wt.	0.17	0.05

[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[1]

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

# of parameters in the model	Factors	R^2	Root mean square error
1	FQS>3	0.18	0.05
2	FSQ>3 Durometer<50	0.21	0.05
3	FQS>3 Durometer<50 Belly Wt.	0.21	0.05
4	FQS>3 Durometer<50 Belly wt. IV>74	0.21	0.05

[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

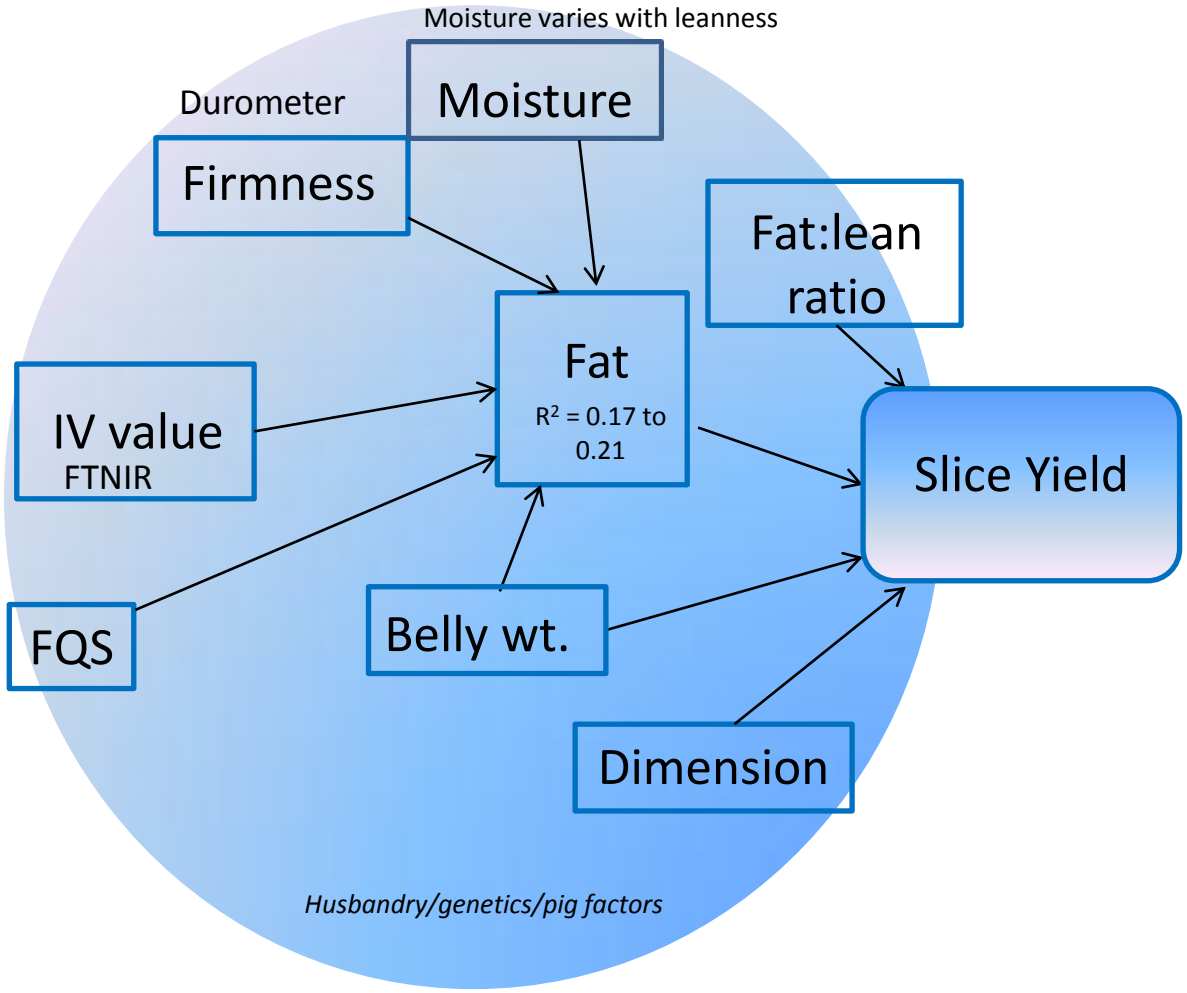
FTNIR IV	Durometer	FQS
• Objective • Results are in the right ranges • Readings seem to be affected by surface effects • Easy to use • Can be incorporated into any computerized grading scheme • Calibration seems adequate, but future improvements may improve precision • Gives indirect measure of fat softness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

*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.

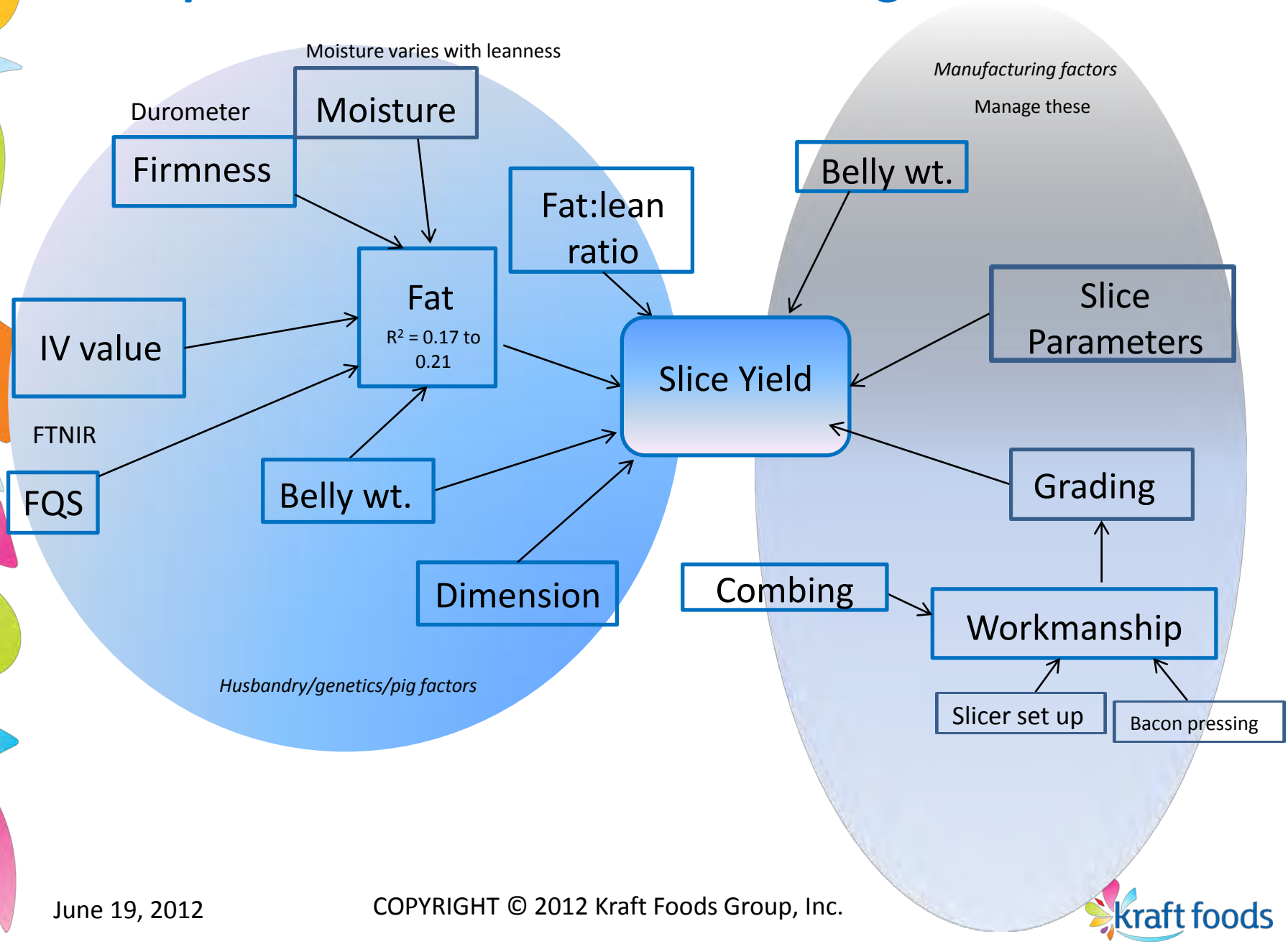
Conceptual Model of Factors Affecting Slice Yield

Slice Yield

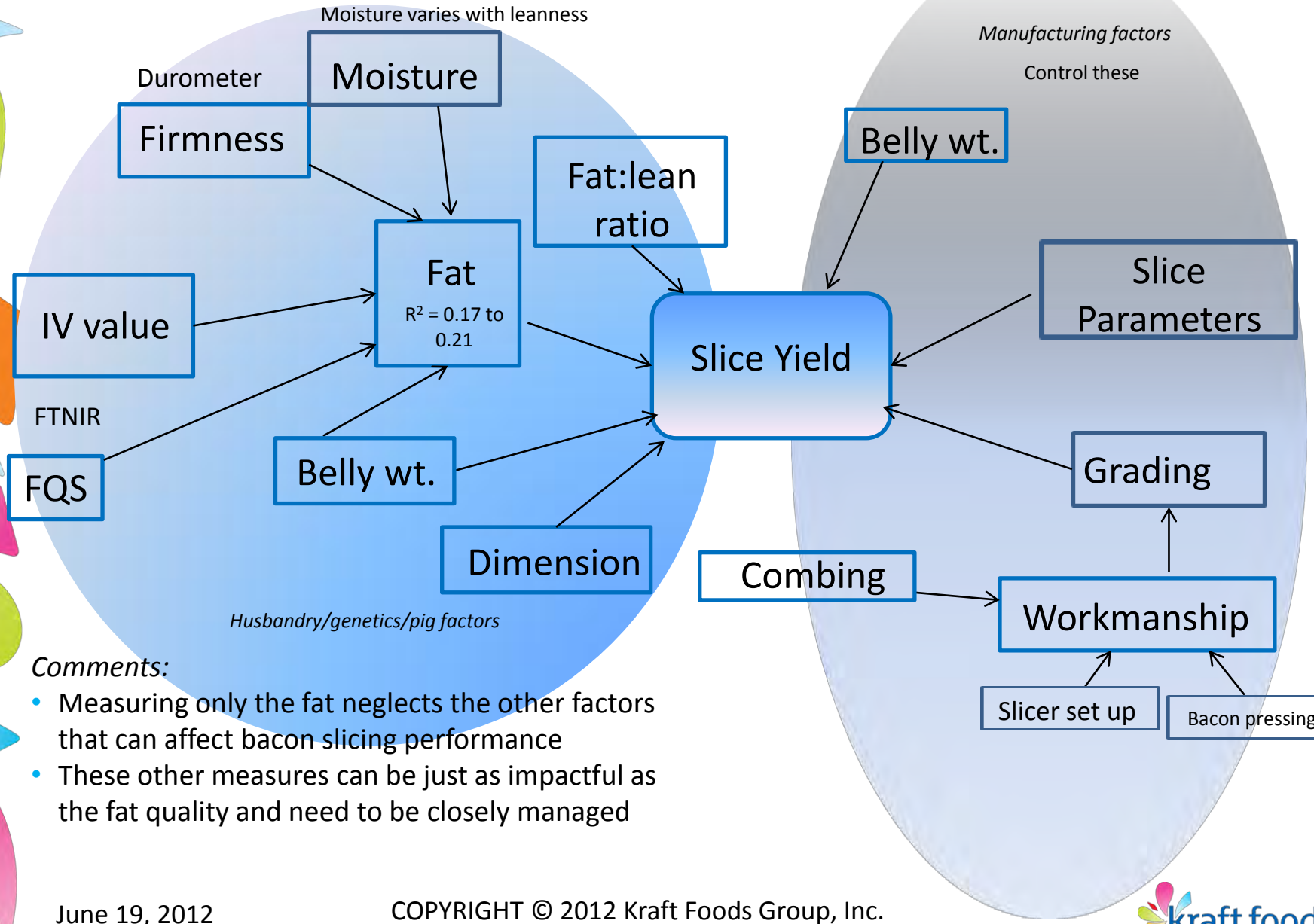
Conceptual Model of Factors Affecting Slice Yield



Conceptual Model of Factors Affecting Slice Yield



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[1]

- 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