KERNEL PROCESSING: PRINCIPLES, TRENDS AND QUANTIFYING EFFECTIVENESS

University of Wisconsin
October 2nd, 2014

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HARVESTER VS. NUTRITIONIST

…. the nutritionist says the silage isn't processed well enough and need to close it down more but when I tried 1.8 mm it plugs …..

….. personally think its doing an awesome job at the 2 mm all kernels are broke at least in 2 pieces most are more than that …

…. nutritionists almost always feel that silage could be better processed ….

…. Nutritionist has become a four letter word around here…….

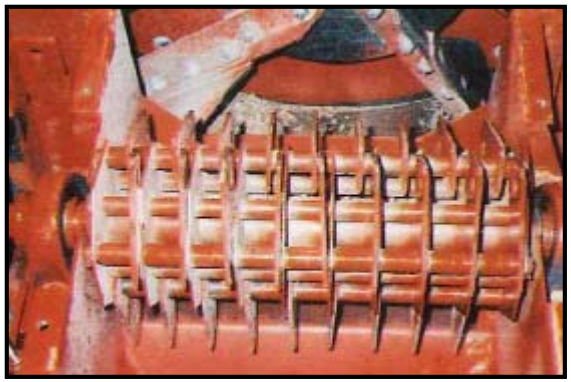
…… I thought the world was coming to the end as our nutritionist came around and said the silage was perfect…..

From Machinery Talk 9/24/2014

Brief History

- Developed for European SPFH in 1980's.
- Migrated to NA in mid-1980's:
  - Tower silo fading, longer TLOC possible
  - Greater knowledge of starch and fiber digestion kinetics
  - Rapid adoption b/c of seamless integration

BRIEF HISTORY



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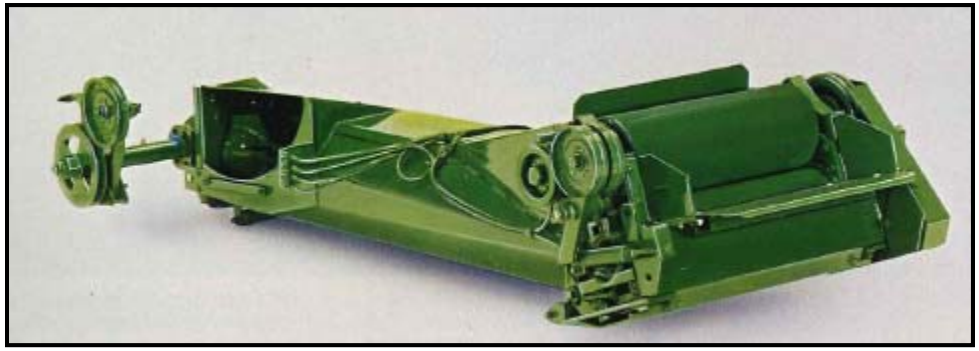


FUNCTION

- Starch fraction (i.e. kernels) processed by:
  - Crushing – clearance smaller than kernel
  - Shearing – roll speed differential
- Fiber fraction processed by:
  - Shearing – roll speed differential

FUNCTION

- Particle-size influences:
  - Starch utilization
  - Physically effective fiber
  - Machine throughput; power reqr.; and fuel use
  - Packing density, fermentation

QUANTIFYING PROCESSING EFFECTIVENESS

Kernel Processing Guidelines

(mass fraction below 4.75 mm)

- > 70% Optimal
- 50-70% Adequate
- < 50% Not adequate

4.75 mm screen

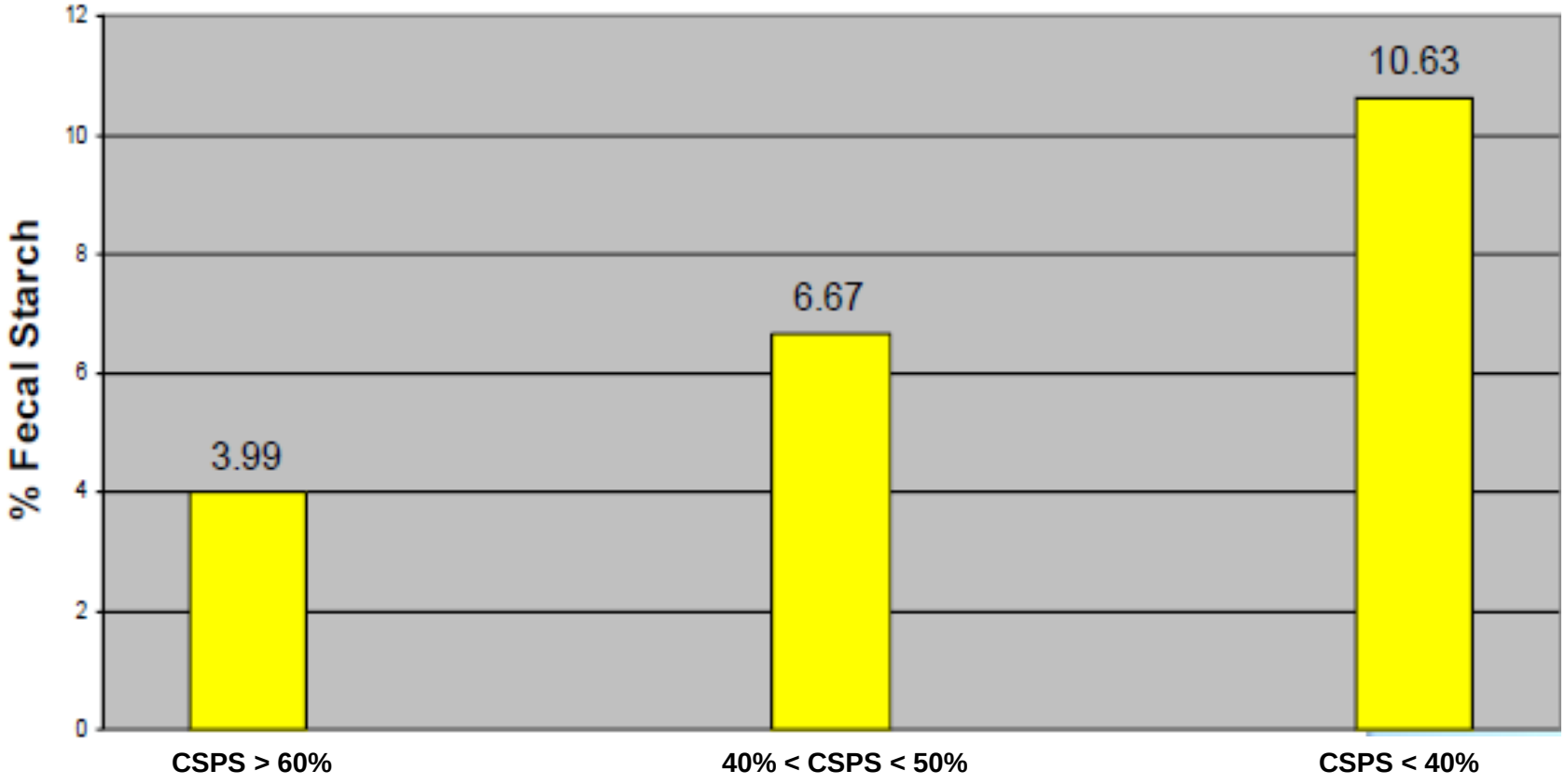
Poor starch availability

Good starch availability

Sieve (mm)	Fiber and starch separations
19	coarse
13	coarse
9.5	coarse
6.7	coarse
4.75	coarse / starch sieve
3.35	medium
2.36	medium
1.18	medium
0.6	fine
pan	fine

QUANTIFYING PROCESSING EFFECTIVENESS

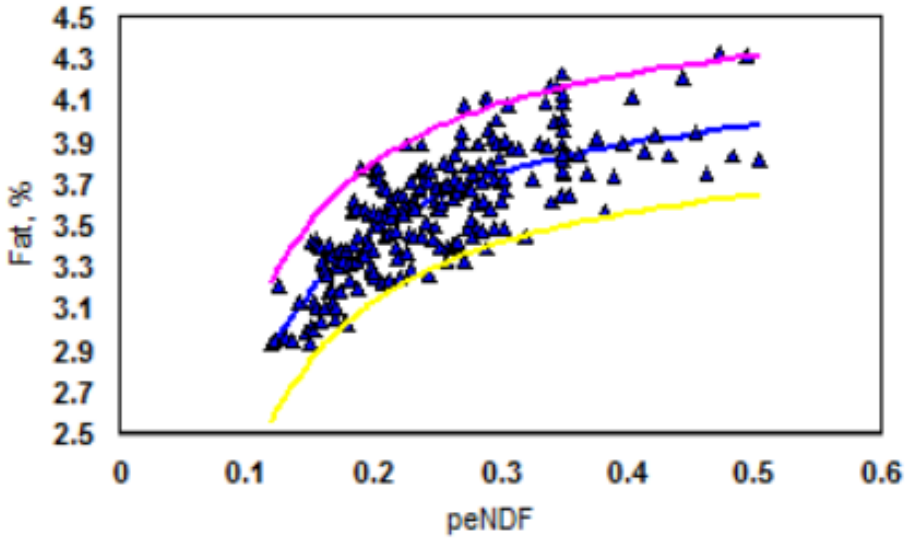
- Desire FS < 5%, optimally < 3%



From Wacker-Driver – Vita-Plus - 2014

Quantifying Effective Fiber

Screen Opening, mm	Recommended Range
19	3 – 8%
8	45 – 65%
1.18	20 – 30%
Pan	< 10%



FUNCTION

- Final physical properties of WPSC altered by:
  - Theoretical length-of-cut (TLOC)
  - Roll clearance
  - Speed differential
  - Tooth profile
  - Machine throughput
  - Moisture, maturity, hybrid

FUNCTION

- TLOC considerations:
  - Typically set at 19 to 30 mm – trending upward
  - Decrease TLOC as crop dries and matures
  - Longer TLOC increases effective fiber and reduces cutting energy but results in :
    - Greater processor energy reqr.
    - Reduced processor throughput
    - Greater processor wear

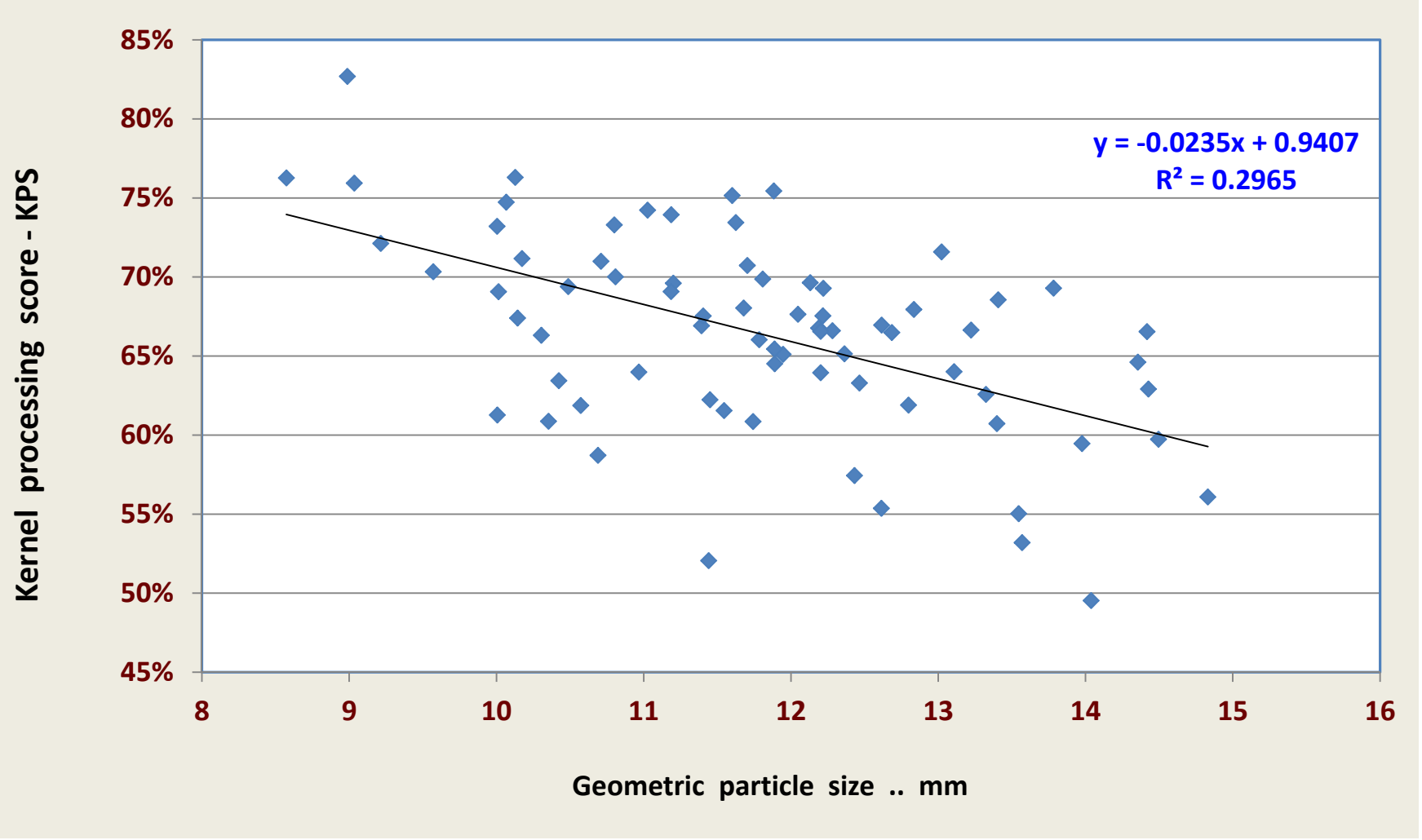
FUNCTION

- TLOC considerations:

TLOC Survey of 70 WI Farms	
TLOC Range	**Number of Samples**
>26 mm	10
26 mm	33
22 mm	22
19 mm	4
<19 mm	1

From Randy Shaver – UW - 2014

QUANTIFYING PROCESSING EFFECTIVENESS



From Randy Shaver – UW - 2014

FUNCTION

- TLOC considerations:
  - Removing knives from cutterhead to increase TLOC
    - Reduces machine capacity
    - Makes feeding processor more challenging

FUNCTION

- Roll clearance considerations:
  - Typically set at 1 to 3 mm
  - Decrease as crop dries and matures
  - Smaller clearance improves processing but results in:
    - Greater processor energy reqr.
    - Reduced processor throughput
    - Greater processor wear

FUNCTION

- Roll clearance considerations:

Roll Clearance Survey of 70 WI Farms	
Roll Clearance Range	**Number of Samples**
>2.5 mm	**2**
2.5 mm	**10**
2.0 mm	**30**
1.5 mm	**11**
1.0 mm	**7**
<1.0 mm	**3**

From Randy Shaver – UW - 2014

FUNCTION

- Speed differential considerations:
  - Typically configured for 20 to 40% - trending upward
  - Greater speed differential improves processing but results in :
    - Greater processor energy reqr.
    - Reduced processor throughput
    - Greater processor wear

FUNCTION

- Speed differential considerations:

Forage Harvester Specific Energy .. hph/ton					
Roll Clearance	1 mm		3 mm		5 mm
Roll Speed Diff.					
21%	3.00		2.76		2.70
42%	3.27		3.00		2.85
	10%		8%		5%

From Shinners et al., 1998

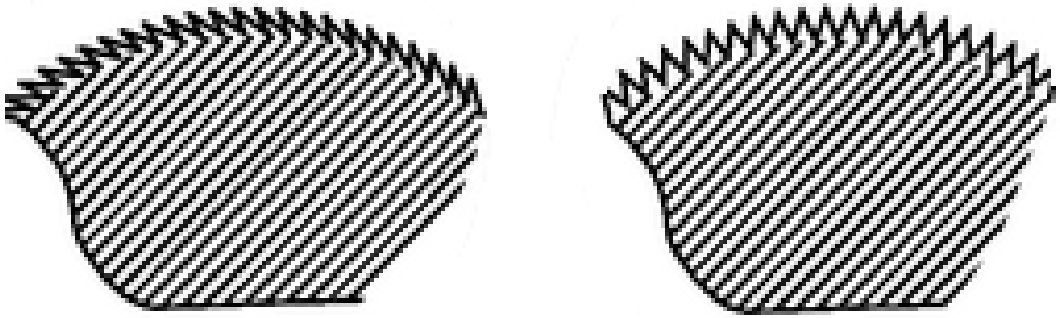
FUNCTION

- Tooth profile considerations:
  - Triangular and saw (angled) teeth are common
  - Typically 100 - 150 teeth per 10 in. diameter roll
  - Cross cut rolls trending
  - As tooth profile shrinks, wear rate increases

FUNCTION

- Tooth profile considerations:

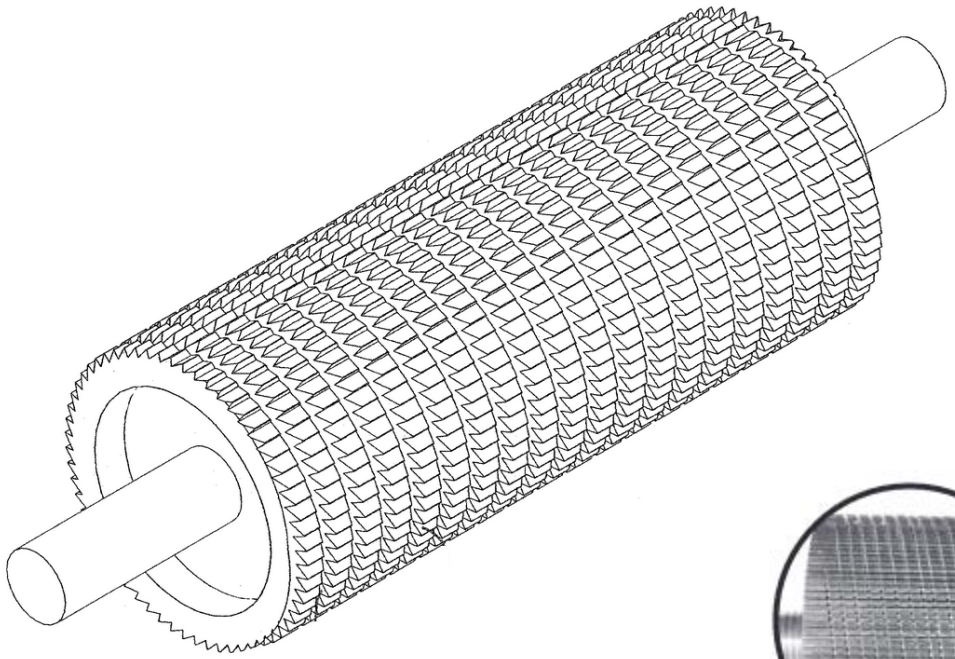
From Krone - 2014



From John Deere - 2014

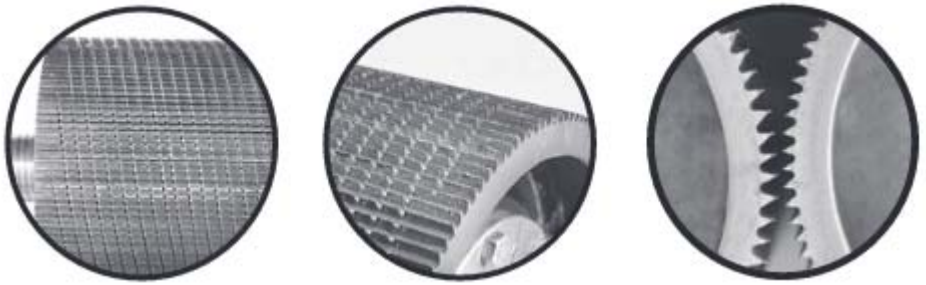
FUNCTION

- Tooth profile considerations:



From US Patent No. US8480019 B1

From Kooima - 2014



From Horning - 2014

FUNCTION

- Processor design considerations:

From John Deere - 2014

PROCESSOR RECOMMENDATION

- Balancing machine, silo and animal needs:
  - DM content of 32 to 36%
  - TLOC – 20 to 26 mm
  - Roll clearance – 1 to 3 mm
  - CPCS score ~60% at harvest, > 70% after fermentation

FUNCTION

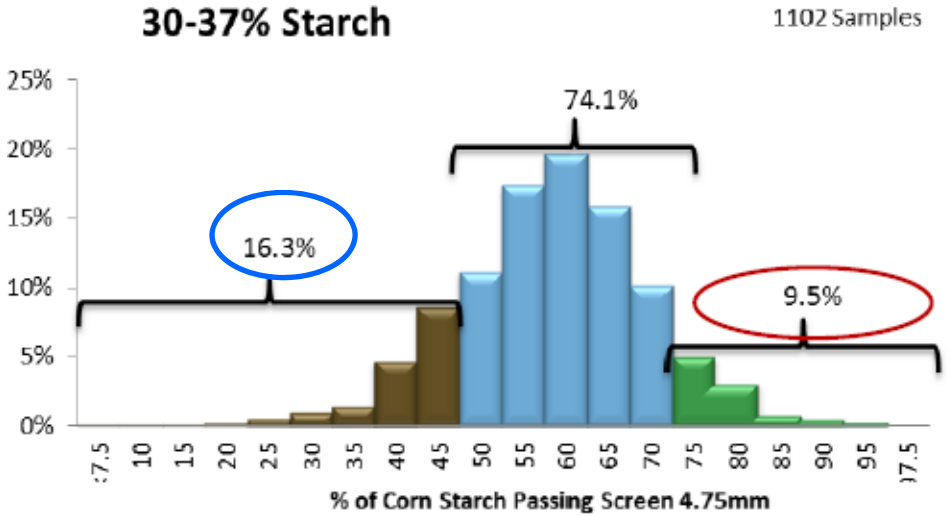
- Crop maturity considerations:

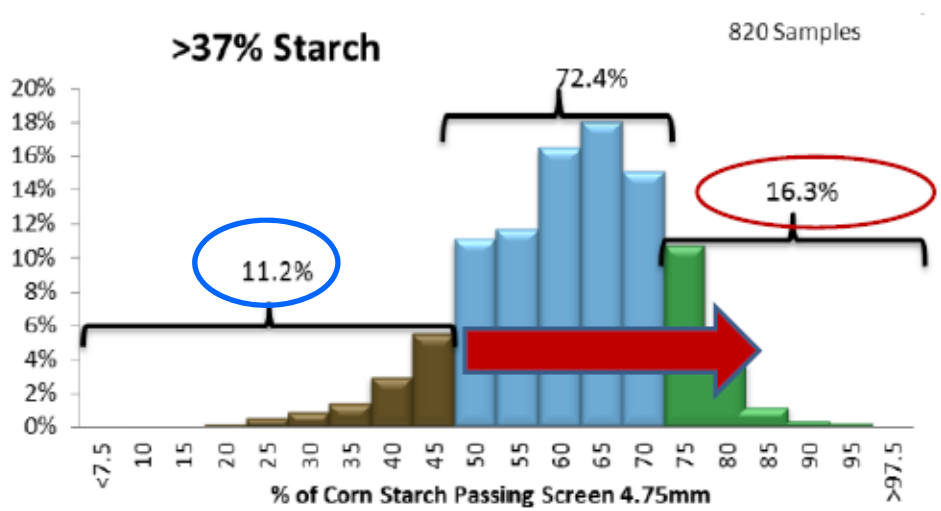
~ Milkline	Unbroken or Merely Cracked .. % of total	Kernel Particle Size .. mm
⅓	14.5_{b}	4.9_{b}
½	12.0_{ab}	4.8_{b}
⅔	8.9_{a}	4.6_{a}

From Shinners et al., 1998

FUNCTION

- Crop maturity and moisture considerations:

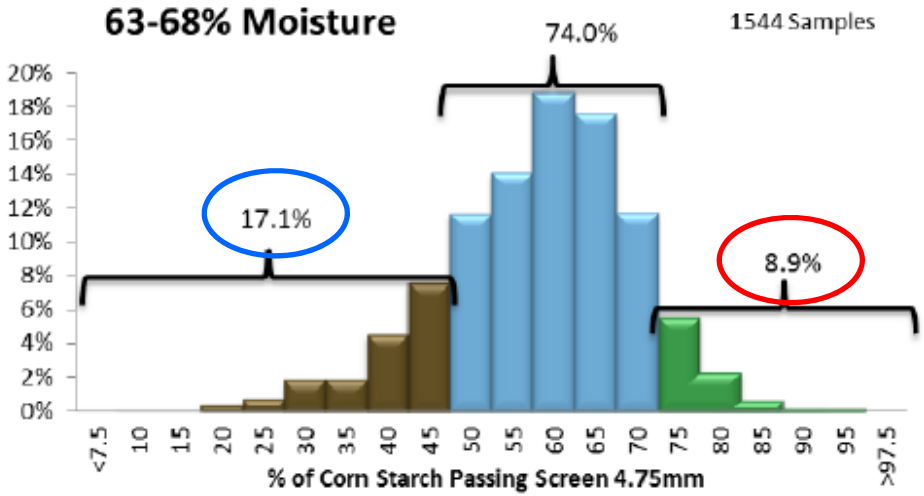


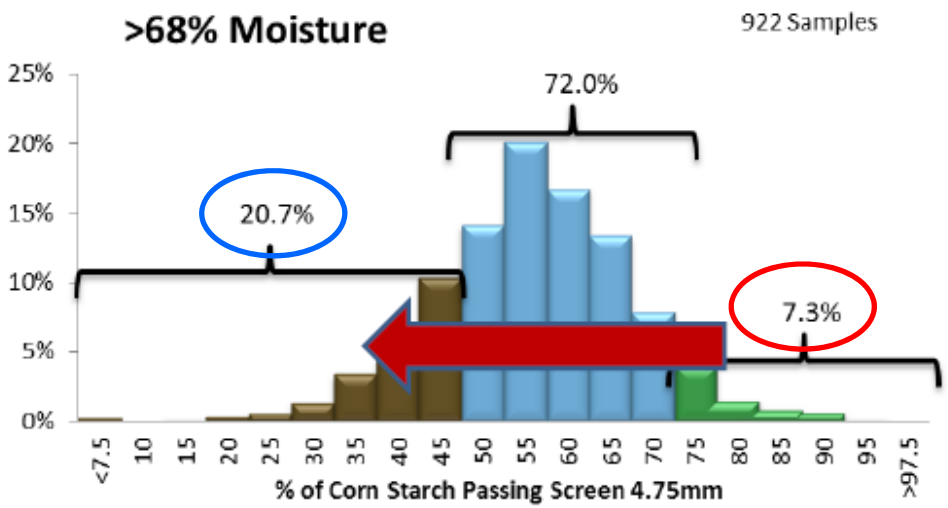


From Wacker-Driver – Vita-Plus - 2014

FUNCTION

- Crop maturity and moisture considerations:





From Wacker-Driver – Vita-Plus - 2014

FUNCTION

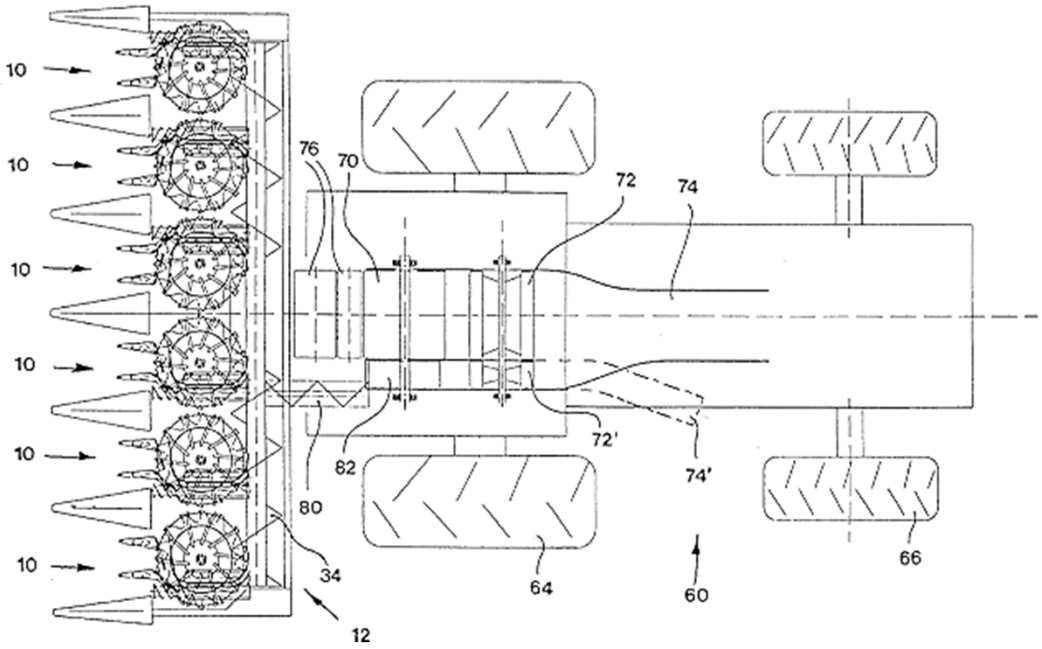
- Crop maturity and moisture considerations :
  - Drier, more mature kernels are “stronger” but maybe more “brittle”
  - Drier, more mature kernels are larger and easier to crush
  - Producers are decreasing TLOC and roll clearance

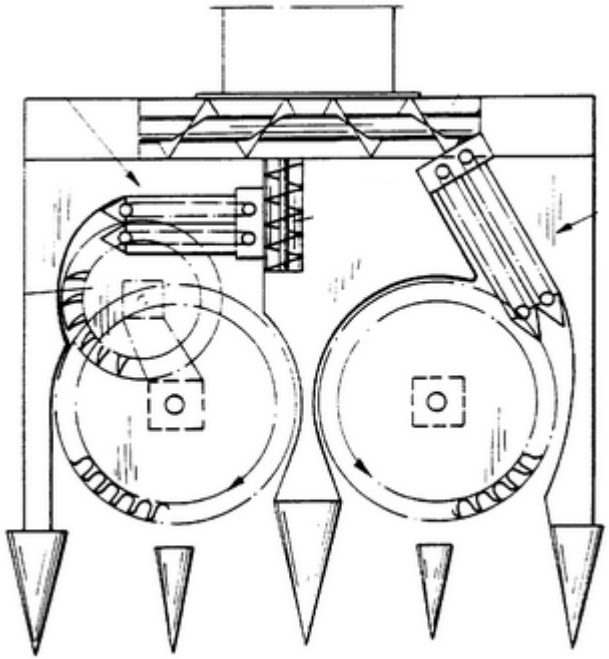
Research Needs

- Root cause of milk yield improvement from highly processed WPCS:
  - Increased fiber digestion from greater shredding?
  - Smaller particle-size of kernel fraction?

Future of Kernel Processing

- Separate TLOC and processing of cob and stalk?





From Patent No. 6119443

Future of Kernel Processing

- Separate TLOC and processing of cob and stalk?

Future of Kernel Processing

- Separate upper and lower plant components?

Research Needs

- Better method of quantifying processed kernel particle-size at harvest….

From Shredlage LLC – 2014

From Pioneer- 2014

QUANTIFYING PROCESSING EFFECTIVENESS

QUANTIFYING PROCESSING EFFECTIVENESS

World Dairy Expo, Madison, WI

Assessment of Corn Silage Kernel Processing Score via Digital Image Processing Techniques

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and
Extension Specialist

October 2, 2014

UW Extension
University of Wisconsin-Extension

Kernel Processing Score (KPS) Determination

- Synonymous with particle size analysis
- Usually done with a Ro-Tap machine and sieves
- Usually done in a laboratory setting
- Producers must send samples off and wait for results

Objective

- Goal: Determine KPS in field during harvest
- How? Image analysis
- Precedent for using image analysis for determination

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Methods

- Measure particle size using image processing
  - Used two different camera resolutions
  - Data collected in ideal laboratory setting
  - Size determination via known object in image

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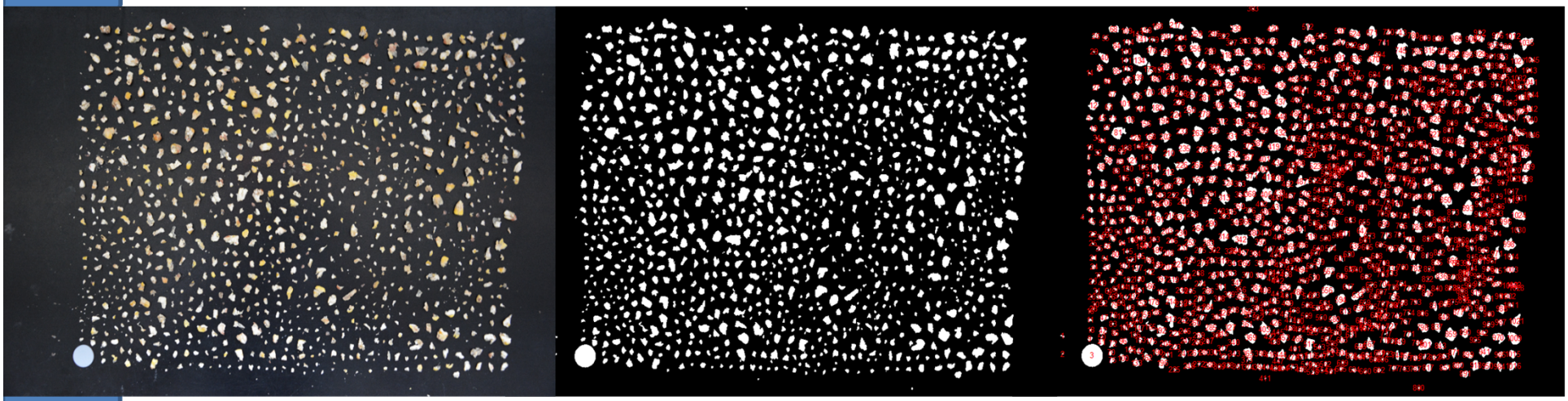
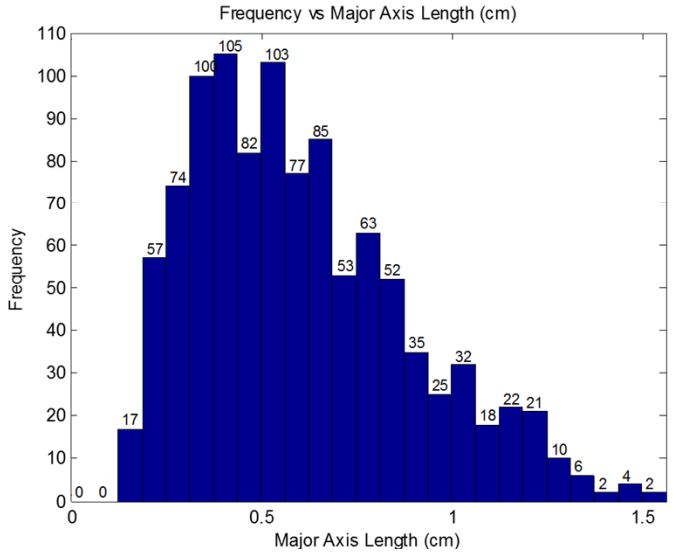
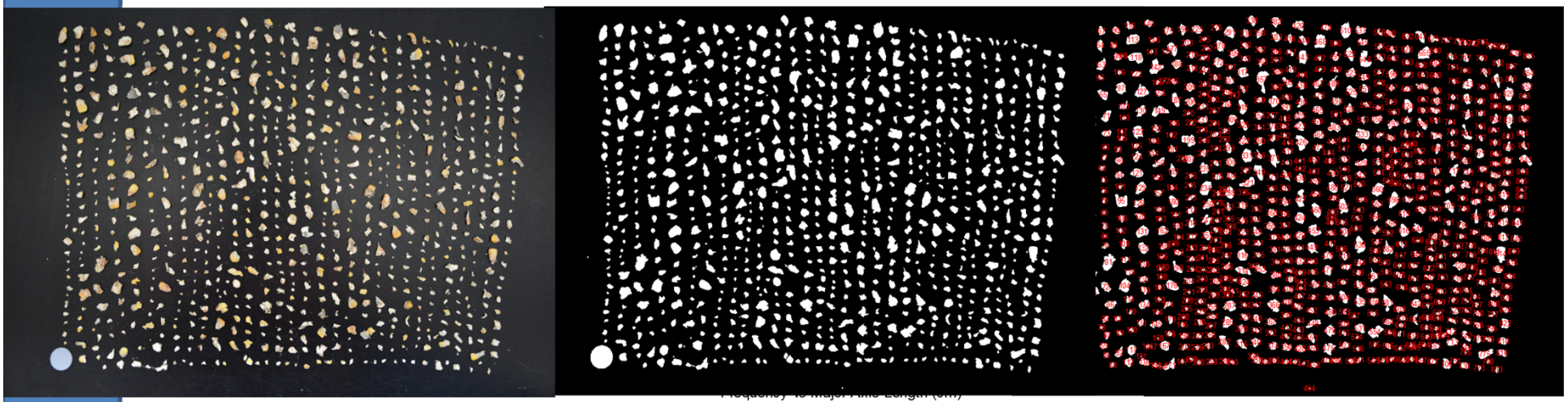
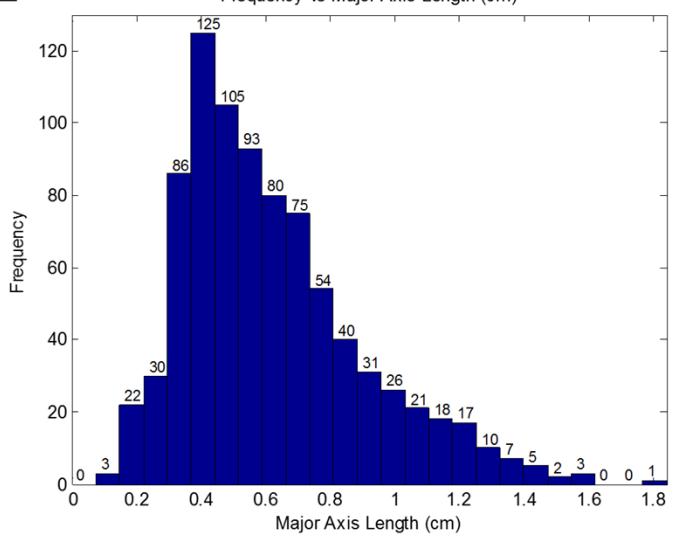
2mm processor gap





3mm processor gap





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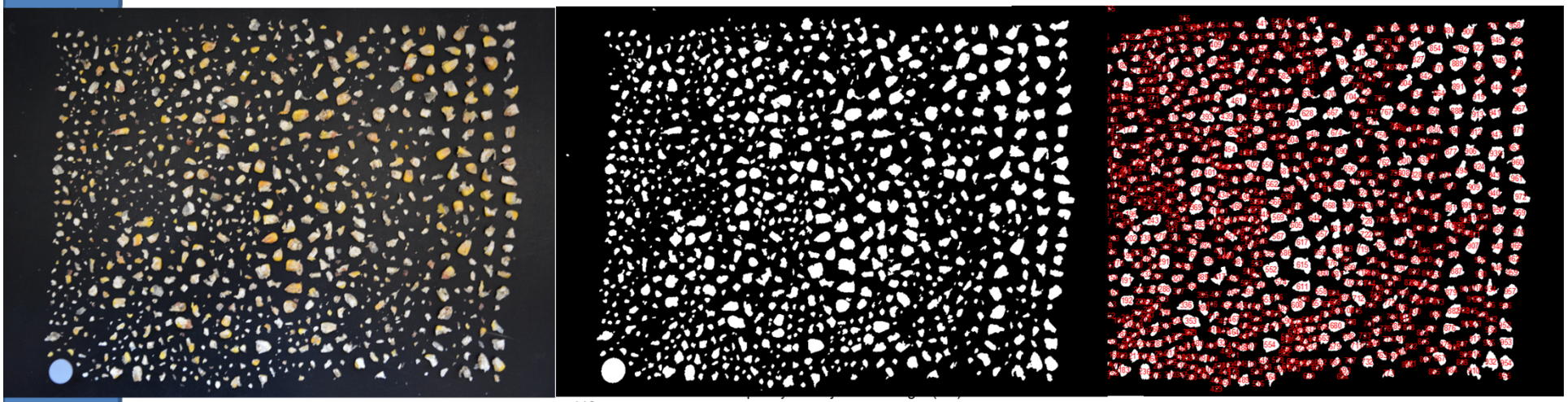
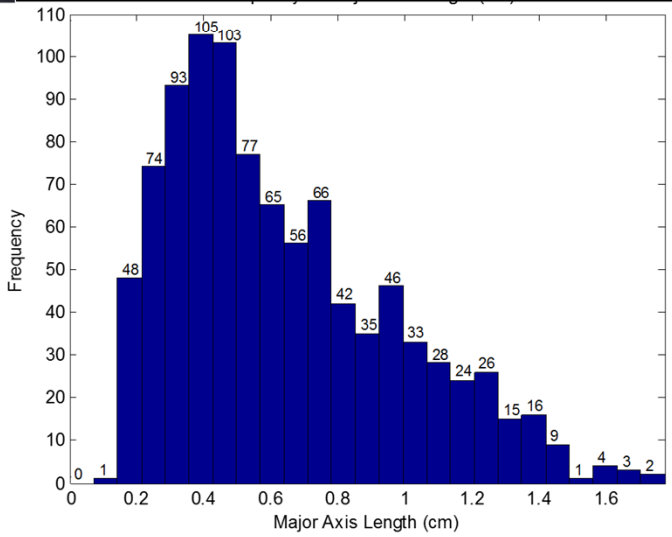
5mm processor gap





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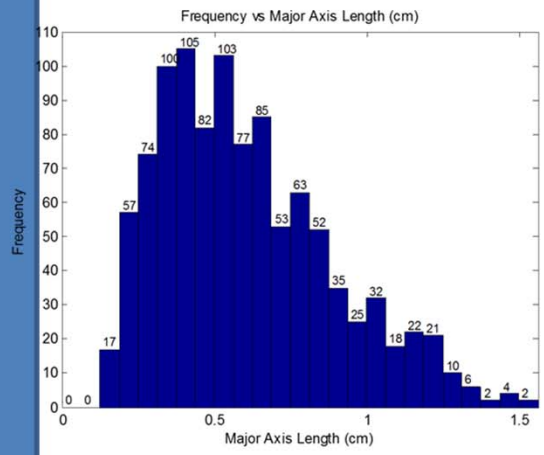
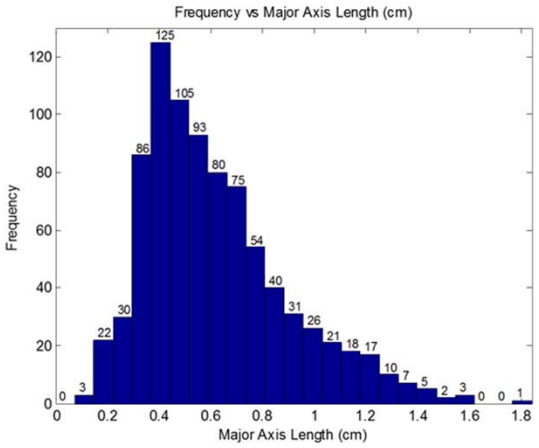
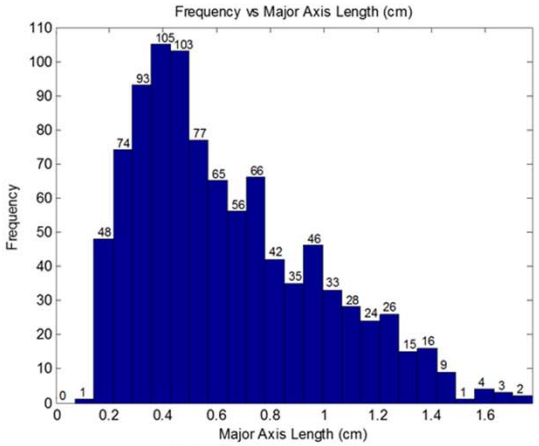
Initial Analysis

- Statistical Analysis (α = 0.05)
  - No difference between processor gaps on mean particle size
  - No difference between camera resolutions
  - Doesn't seem right?







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Proper Analysis

Statistical Analysis
($\alpha = 0.05$)

- Significant difference between processor gaps on major axis particle size (P = 0.0002)
- No difference between camera resolutions
- Much better!

The SAS System

Effect=resolution Method=LSD(P<0.05) Set=1

Obs	resolution	spacing	Estimate	Standard Error	Letter Group
1	high		0.5159	0.02979	A
2	low		0.5090	0.02979	A

Effect=spacing Method=LSD(P<0.05) Set=2

Obs	resolution	spacing	Estimate	Standard Error	Letter Group
3		5	0.6878	0.03649	A
4		3	0.4411	0.03649	B
5		2	0.4084	0.03649	B

Next Steps

- Image processing viable for KPS determination
- Calibrate laboratory analysis for comparison to Ro-Tap determination method
- Assess feasibility of kernel detection in whole plant samples
- Smart phone app development

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