Seed Conditioning Technology

(Agronomy / Horticulture 338)

Seed Science and Technology
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Alan Gaul
Seed Conditioning Specialist
515-294-4011
agaul@iastate.edu

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### Why Condition Seed?

- Soybeans
- Adzuki Beans
- Seed Corn

- Threshing & Moisture Removal
- Weed Seed & Foreign Material
- Diseased & Immature Seed
- Improve Appearance, Uniformity
- Add Protective Coatings

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### Additional Conditioning Issues

- Harvest
- Seed Extraction
- Threshing
- Drying
- Specialized Treatments

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### General Conditioning Flow Diagram

- **Objectives:**
  - Remove All Contamination
  - Minimize Seed Loss
  - Remove Low Quality Seed
  - Maximize Capacity
  - Minimize Labor Required

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### Review Topics

- Conditioning Applications
- Harvest & Storage Issues
- Material Handling Basics
- Separation Methods
  - Pre-cleaning / Preparation
  - Cleaning & Sizing
  - Upgrading Equipment*
- Treating & Packaging*
- Definitions & Quality Tests
- Pending Lab Discussions

*more detail in 2nd presentation

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### Production Facilities

Midwestern seed plants are gradually becoming larger, more complex industrial facilities.
**Basic Soybean Flow Diagram**

- Harvest
- Pre-Cleaner
- Bulk Storage
- Air Screen Cleaner
- Spiral/Belt Separator
- Gravity Separator
- Seed Treater
- Bagging Line
- Finished Seed

**Typical Flow for Seed Corn**

- Harvest
- Ear Corn Plant
- Pre-Cleaner
- Bulk Storage
- Air Screen Cleaner
- Gravity Separator
- Seed Treater
- Bagging Line
- Finished Seed

**Harvest & Storage Concerns**

- Limit Mechanical Damage
  - Reduce cylinder or rotor speed
  - Avoid running at partial capacity
- Avoid Varietal Contamination
  - Extensive cleaning is required
- Maintain Quality in Storage
  - Limit incoming moisture
  - Pre-clean seed if possible
  - Level bin and aerate properly
  - Careful drying may be needed to reach safe moisture levels

**Ear Corn Harvest & Receiving**

- Picking
- Husking
- Receiving
- Sorting
- Drying
- Shelling

- Wet ear corn is harvested & transported to plant
- Husks are removed and "off types" sorted manually
- Husked corn is then dried prior to shelling

**Ear Corn Harvest Issues**

**ADVANTAGES**
- Early Harvest of High Moisture Corn
- Field Loss Reduction (Fungi, Insects, Weather)
- Potential for Double Crop in Warm Climates
- Additional Time for Post Season Operations
- Visual Inspection for Quality Control

**DISADVANTAGES**
- High Initial Investment for Ear Corn Facilities
- High Labor Costs for Sorting & Handling
- High Fuel Cost for Drying

**Husk & Sort Facilities**

- Truck Unloading
- Distribution Conveyor
- Feeder
- Sorting Belt(s)
- Husker
- Husked Corn
- Husk & Discard
- Ear Corn Dryer
- Sorted Corn
- Renue
- Rogue
- Discard
**Ear Corn Dryer Type Diagrams**

- **Single Pass**
- **Double Pass**
- **Single Pass Reversing**

*Based on Airflow Pattern*
- Bin Qty for Series Airflow
- Airflow Direction Changes

*Key Differences:*
- Management Complexity
- Airflow Volume Required
- Energy Efficiency

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**Production Ear Corn Shellers**

- Axial Flow Configurations
- Round Bar or Perforated Cage
- Rotor Speed affects Seed Damage
- MUST maintain Product in Hopper

*Conical Cage*

*Round Bar Cage Perforated Cage, Integral Cob Blower*

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**Automated Shelling Lines**

*Typically Found at Larger Seed Research Operations*

- Sorting
- Sheller
- Cleaner
- Color Sorter
- Treater
- Packeting

*Automated batch operation*
- Pneumatic seed transfer
- Typically 12-20 ears per batch

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**Material Handling Systems**

- Elevator Legs
- Belt Conveyors
- Drag Flight Conveyors
- Vibratory Conveyors
- Pneumatic Conveyors
- Gravity Spouts and Letdowns

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**Mechanical Damage during Conditioning**

- **Auger Damage**
- **Moisture Effect**

*Germination vs Sequence for 2 Moisture Levels*
Seed Science Center

**Mobile Conveying Equipment**
- Portable Belt Conveyor
- Screw Conveyor
- Pneumatic Conveyor

**Conventional & Continuous Cup Legs**
- High Capacity
- Compact
- Easily Enclosed
- Lower Cost
- Vertical Lift Only
- Self Cleaning
- Limited Capacity
- Maintenance
- Higher Cost

**Vibratory Feeders & Conveyors**
- Variable Feeder
- Receiving Conveyor
- Transfer Conveyor

**Letdown Devices**
- Letdown Ladder
- Spiral Letdown

**Mechanical Damage Detection**
- Unloading
- Receiving Leg
- Belt Conveyor
- Air Screen Cleaner
- Cleaner Leg
- Inclined Spout

**Minimizing Mechanical Seed Damage**
- Reduce seed velocity
  - Minimize drop height in spouts or transfer points
  - Use lowest RPM needed to provide required capacity
  - Use a larger conveyor running at lower speed
  - Use the lowest possible incline angle
- Reduce impact, abrasion, crushing or shearing actions
  - Eliminate pinch points and sharp edges
  - "Run in" conveyor to polish rough surfaces prior to use
  - Run most conveyors at (or near) Full Capacity
  - Consider rubber or plastic product contact surfaces
  - Modify conveyors if needed to avoid crushing seed
- Take extra precautions at cold operating temperatures
### Seed Science Center

**Dry Granular Separation Principles**
- Separation based on Differences in various Physical Properties
- Common principles used:
  - Aerodynamics/Terminal Velocity
  - Approximate Seed Size
  - Seed Dimensions (L-W-T)
  - Seed Shape (Rolling Resistance)
  - Product Density
  - Color Differential
- Most “real world” applications require multiple techniques

**Tools of the Trade (1/4)**
- **Aspirator**
  - Vertical or inclined air column
  - Usage: Pre-cleaning or removal of light contaminants
- **Air-Screen Cleaner**
  - One or two aspiration columns
  - Multiple perforated screens
  - Usage: Removal of light contaminants, undersized, and oversized material

### Seed Cleaning - Physical Properties
- Aerodynamic Properties (terminal velocity): Aspirator
- Seed Size & Shape: Air Screen Cleaner
- Dimensional Separation: Length, Width, & Thickness Sizers
- Rolling Resistance: Spiral and Belt Separators
- Specific Gravity (Density): Gravity Separator & Destoner
- Color (UV, visible spectrum, NIR): Color Separator
- Surface Texture: Velvet Roll, Vibratory, Magnetic Separator
- Affinity for Liquids: Buckhorn Separator
- Electrical Characteristics: Electrostatic Separator

### Types of Contamination
- **Foreign Material** - Plant parts, stones, dirt, bugs, etc.
- **Other Crop Seed** - “Alternative” crops
- **Weed Seed** - Other undesirable non-crop seeds
- **Mechanical Damage** - Chipped or broken seed
- **Varietal** - Other varieties of the intended crop
- **Physiological** - Physical or biochemical issues
- **Pathological** - Seed diseases and/or insect damage

### Aspirator Examples
- **Conical (Spout)**
- **Multiple Pass**
- **Cascade Aspirator**
- **Scalperator**
- **Scalping Aspirators**
  - Combined Scalping Reel and Aspiration in same machine
  - Simultaneous oversize and light material removal
  - Common for high capacity removal of trash from seed

Images courtesy of LMC, Forsberg, Kice, and SeedTech Systems.
• Air and Sieve Operations
• Removes FM, Light, Broken, Undersize, & Oversize Seed

Screen Perforations
• Hole geometry & size determined by application
• Layout affects capacity and screen efficiency
• Size specified in English or Metric
• Multiple screen sizes are typically used for most seed applications

Screen Selection
• Achieves maximum removal of foreign material and minimum removal of good product
• Removal of foreign material by cleaner improves effectiveness of other downstream processes

Screening / Sizing Terminology
Screening Terminology:
• “Scalping” – Removal of Oversize Material from Product
• “Sifting” – Removal of Undersize Material from Product
• “Sizing” – Dividing the Product into two Size Ranges
• “Efficiency” is based on the desired operation type

Screening / Sizing Efficiency
Sifting Efficiency (undersize removal):
• Percent of Total Undersize Material passing “thru” the screen
• Screen Capacity is limited by desired sifting efficiency
Scalping Efficiency (oversize removal):
• Percent of Total Oversize Material passing “over” the screen
• Scalping Efficiency may be close to 100% for spherical seed
**Tools of the Trade (2/4)**

**Indent Cylinder or Disc Separator**
- Indented pockets sized for length separation
- Usage: Separation of long from short material (ex: wheat/oats)

**Precision Sizer**
- Rotary cylinders with Round or Slotted perforated holes
- Usage: Sizing or removal of contaminants based on Width or Thickness

**Seed Size Definitions**
- Same thickness, different width
- Same width, different thickness
- Same width & thickness but different length

**Length Grading – Indent & Disc Separator**

**Laboratory Indent Cylinders**
- Traditionally operated in “batch” mode
- Newer machines capable of either batch or continuous flow
- Used for Cylinder Selection and Cleaning Small Lots
- Adjustments include Size, Speed, & Trough Position

**Disc Separator**
- "V" ("Vetch"), "V"+Width (mm), V2.5 thru V6.5
- "R" ("Rice"), "R"+Width (mm), R 3.5 thru R6
- Square (desticking), Letter Designation

**De-Sticking Sunflowers**
- Stems and sticks are hard to remove using conventional perforated screens
- Lifting sunflowers from sticks can be accomplished using either a disk or indent cylinder separator

*Images Courtesy of Westrup USA, Inc.*
Width and Thickness Sizer

Width – Round Hole
Thickness – Slotted

Sizing Flow Diagram (4 Sizes + Discard)

Typical sizing stack uses multiple machines to create desired sizes
Cylinder quantity is based on flow rate at each machine location
Cylinder capacity depends on % "thrus" and desired efficiency

Sizing Cylinder Selection

Cylinder Selection Factors:
• Fractional quality evaluation
• Percent breakout by fraction
• Size range limits (plantability)
• Marketing requirements

Sizing Cylinder Capacity

Capacity is typically rated at 95% efficiency (or higher)
Cylinder capacity is higher for round hole configurations
Cylinder capacity increases with higher percentage of thrus

Flat Screen Sizing (modular cleaners)

• Alternate to cylinder sizers on seed corn applications
• Limited evidence of reduced mechanical damage, possibly greater for round seed (Popp, 2003)
• Sizing efficiency is typically lower than for cylinders
• Capacity is less than equivalent air screen cleaner

Tools of the Trade (3/4)

Spiral Separator
• Inclined helical flights sloped to match rolling speed
• Usage: Separation of spherical from non-spherical products

Belt (roll) Separator
• Inclined moving belts
• Usage: More precise separation based on differences in rolling speed of various products
Shriveled or Oblong Seed Causes

- Immature Seed
- Diseased Seed
- Frost Damage
- Field Conditions
- Drought
- Other Factors

Static Spiral Examples

Images courtesy of Profile Industries

Rotary Spiral Examples

Single Core  Multiple (4) Cores  Core Replacement

Belt Separator

- Original "Draper Belt" design – single slope
- Later modified to use dual belt slope
- Provides multiple fractions, fewer collisions
- Multiple belts stacked to provide more capacity

Belt Separator Samples

Round (95%)  Discard #1 (0.4%)

Tools of the Trade (4/4)

Gravity Separator
- Reciprocating inclined fluidized bed to "float" light from heavy
- Usage: Density separation of light weight or heavy product

Color Sorter
- Optical separation based on differences in color or intensity
- Usage: Removal of dark and/or light discolored material
**Fluidized Bed Density Separation**
- Destoner
  - Two Density Fractions
  - Removes Heavy Material

**Gravity Separator**
- Continuous Density Range
- Multiple Fractions Possible
- Removes Low Density Seed

**Optical Detection & Separation**
- Color Sorting Equipment
  - Provides Two Color Fractions
  - Removes Light or Dark Material

**Treating & Coating**
- Seed Coating
  - Provide Pathogen Protection
  - Improve Planter Performance
  - Better Product Appearance
  - Increase Seed Size (Pelleting)

**Seed Pelleting**
- Automatic Batch
  - Continuous Flow
  - Used to Apply Treatment or Coatings:
    - Correct Proportion of Seed & Chemical
    - Acceptable Appearance & Product Flow
    - Proper Application Rate
    - Uniform Seed Coverage

**Packaging**
- Package Type Factors:
  - Market Requirements
  - Volumetric Issues
  - Desired Automation
  - Downstream Handling Equipment Availability

**Storage and Shipment**
- Warehouse Considerations:
  - Space Requirements
  - Material Handling Facilities
  - Possible Climate Control
  - Traffic Control and Security

Images courtesy of Seed Processing Holland and Gustafson Equipment (Bayer).
Common Quality Control Measurements

- Moisture Content (%)
- Test Weight (lb/bu or kg/hectoliter)
- Broken Seed (BCFM or Split %)
- Seed Coat Damage (%)
- Seed Count (seeds/lb, TKW)
- Visual Defects (%)
- Packaged Units (weight or count)
- Flow Rate (lb/hr, bph or tons/hour)
- Discard or Fraction Percentage (%)
- Separation Efficiency (%)
- Good Product Yield (%)
- Defect Concentration (%, G:B ratio)
- Measurement variability

Moisture Measurement Technology

- Air oven dryer is the measurement standard
- Other meters are calibrated against oven
- Electrical meters - resistance, capacitance, or near infrared (NIR)
- Brown-Duvel - high MC, frozen seed

Density Definitions

Bulk Density
- Typically called “Test Weight” for most seed applications
- Weight of a given volume of seed, INCLUDING void spaces
- Measured by weighing a container filled under controlled conditions
- Very commonly used for both seed and grain applications

Particle Density
- Sometimes also called “Kernel Density” or “Seed Density”
- Weight of a seed volume EXCLUDING void spaces
- Seed volume measured by liquid displacement or a gas pycnometer

Specific Gravity
- Ratio of particle density to water (specific gravity of water = 1.0)

Test Weight Devices

- Bulk density measurement
- Weight per unit volume
- English – lbs per bushel
- Metric – kg per hectoliter
- Tends to correlate well with seed quality parameters

Split and BCFM Percentages

- Splits – Based on 10/64 Slotted Screen (%)
- BCFM (Broken Corn & Foreign Material) – Based on 12/64” Round Screen
- Screen Shaker to Minimize Variability (30 strokes)
- Typically 500g or larger sample

Seed Coat Mechanical Damage Tests

Sodium Hypochlorite Soak
- Minimal Damage
- Limited Staining
- Good Quality
- Slight Damage
- Some Swelling
- Wrinkled Coats
- Severe Damage
- Rapid Swelling
- Loose Seed Coats

Fast Green Dye Test
- Minimal Damage
- Limited Staining
- Good Quality
- Slight Damage
- Minor Staining
- Storage Concerns
- Severe Damage
- Embryonic Staining
- Poor Germination

- Dilute Bleach Solution (5:1)
- 5 Minute Soaking Interval
- Commercial Dye Solution
- Stains Exposed Starch
Visual Defect Percentages

- Visual Observation (light & dark %)
- Possible to partially automate using fast green dye, image processing, or other methods
- Tends to be very subjective - operator effects

\[
\text{Bad/Good Ratio} = \frac{\text{Defect Qty}}{\text{Good Qty}} \quad \text{Sort Efficiency} = \frac{\text{Reject Defect Qty}}{\text{Total Defect Qty}} \times 100
\]

Typically tracked over time to monitor for possible process changes or optimize adjustments

Seed Count / Size Relationships

- Seed is a biological product with variable size, shape, and density
- Seed Count provides an approximate way to quantify average seed size
- The result tends to vary based on seed dimensions, shape, and weight
- Units are typically expressed as either seed count (seeds/lb) or TGW (grams per 1000 seeds)
- Conversion Equation:
  \[
  \text{Seeds/lb} = \frac{453.6 \times 1000}{1000 \times \text{Seed Wt}}
  \]
- Sample size is application dependent

Typical Seed Counter Applications

- Rough estimate of seed size for a given variety or seed lot
- Quantify differences between seed sizes within the same lot
- Estimate seed size differences between multiple fractions from gravity tables or other separation processes
- Calibration of weight-based seed treaters for newer systemic products using “per seed” application rates
- Quantify blend proportions for integrated refuge products
- Calibration of weight-based bagging scales for high volume bagging operations and seed quantity based labeling
- Packet filling for research or high-value seed applications
- Newer devices may provide additional sample analysis tools

Mechanical Seed Counter Examples

- Multiple feeder designs
- Total vs Batch Operation

Counter Calibration

- Calibration sample - ten sets of 100 seeds each
- Combine the 10 sets and carefully pour 1,000 seed calibration samples into counter
- Start the counter and run until all seeds have been counted
- Final count should be within +/- 2 seeds
- Adjust counter and repeat test if required

Effect of Counting Speed on Seed Count

- Limit Speed for Accurate Counts
- Compensate for Seed Size
New Optical Imaging Counter

- Loaned by Process Vision (Richmond, VA)
- Rapid 2D counting and sample analysis
- Evolving to include additional capabilities
- Also using to analyze spiral testing results

Basic Separation Efficiency Concepts

- Defined by the intended process goals
  - Recovery (removal) of contaminants ("removal efficiency")
  - Recovery of good product ("good product yield")
  - Separation efficiency (seed recovery adjusted for discard levels)

Sample Flow Calculations (Defect Removal)

Given weights of timed samples from each fraction
- Can estimate flow rate and fraction percentages
- Grade samples to determine defect concentration
- Can also estimate defect removal rate
- Similar calculations possible for most operations

<table>
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<tr>
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<th>Sample Weight (lb)</th>
<th>Sample Time (sec)</th>
<th>Flow Rate (lb/hr)</th>
<th>Machine Fraction (%)</th>
<th>Defect Conc. (%)</th>
<th>Defect Flow Rate (lb/hr)</th>
<th>Defect Percent (%)</th>
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<td>20</td>
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Note: Calculations shown assume sample time base is not equal

Sample Flow Calculations (Yield)

Given weights of timed samples from each fraction
- Can estimate flow rate and fraction percentages
- Grade samples to determine defect concentration
- Can also estimate defect removal rate
- Similar calculations possible for most operations

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</tr>
</tbody>
</table>

Note: Calculations shown assume sample time base is not equal

Hypothetical Separation Graph

Statistical Process Monitoring (SPC/SPM)

“Process watching” for change detection
- Examples:
  - Xbar (average)
  - Range (max-min)
  - Standard Deviation (s)

Overall variation components:
- Random, Short Term Baseline
- Non-random, Long Term Variation (to be eliminated)

Shewhart Control Chart
Review and Discussion

- Typical seed separation methods are based on physical differences
- Machine principles may involve size, shape, density, and/or color
- Multiple machines can improve results and minimize seed loss
- Process sequence can often be important for good results
- Understanding characteristics of various contaminants and related equipment capabilities can be useful for difficult separations

Pending Lab - Seed Corn Process

- Shelling & Aspiration
- Air-Screen Cleaner
- Color Sorter
- Sizing
- Gravity Table
- Seed Treater
- (Packaging)

Seed Conditioning Lab Location

Seed Conditioning Lab - Upper Level

Station Sequence:
0) Cleaner, Batch Sizer, Counter (L)
1) Air-Screen Cleaner (L)
2) Satake color sorter (U)
3) Seed Sizing Stack (U)
4) Oliver gravity (L)
5) BMC Treater (L)

1 - Sample Analysis & Cylinder Verification

- Clean seed prior to sizing
- Create 4 seed sizes
- Evaluate size %, seed count
Station 2: Satake Color Sorter

- Review Operation at four dark trip levels
- Each group runs one setting
- Collect timed sample weights
- Evaluate sample quality
- Calculate: % Discard by Fraction and Defect Removal Efficiency

Station 3: Sizing Stack

- Timed samples have been collected in advance to save time
- Evaluate each sample to verify sizing efficiency for each stage
- Estimate flow rate, sized fraction percentage, and efficiency

Station 4: Oliver Gravity Separator

- Review concepts and demonstrate operation
- Collect 3 timed sample weights – Light, Medium, and Heavy (1 per group)
- Record sample weight and related run time
- Lab sample analysis

Station 5: BMC Batch Seed Treater

- Review basic components, product flow, and operation
- Collect 3 timed sample weights – Light, Medium, and Heavy (1 per group)
- Record sample weight and related run time
- Lab sample analysis

References & Acknowledgements

- Seed Conditioning - Technology, Volume 2A-B. Gregg, B.R. 2010
- Seed Processing and Handling. Vaughn, Gregg & Delouche. 1968
- Managing Grain After Harvest, Bern. 2005 (AE 469/569 textbook)
- Seed Science and Agronomy Department archives
- ISU Seed Science workshop presentations (2006-2013)
- Various websites, including www.gipsa.usda.gov (seed images)
- Various Industry Brochures, Operator's Manuals, and Discussions:
  - Advanced Sort Industries - Seymour, IN
  - AEC Enterprises - St. Charles, Iowa
  - ArrowCorp, Inc. – Winnipeg, Manitoba
  - Ball-Coleman (ST5) - Chicago, IL
  - Buhler Sortex - Stockton, CA
  - Carter-Day Int'l – Minneapolis, MN
  - Cimbra Battery Co. – Urbandale, IA
  - Crippen Manufacturing - St. Louis, MI
  - Forsbergs, Inc. - Thief River Falls, MN
  - Harada Sanyo - Ageo, Saitama, Japan
  - LMC Manufacturing - Donalsonville, GA
  - Rice Manufacturing - Wichita, KS
  - Oliver Mfg. - Rocky Ford, CO
  - Profile Industries - Rogers, MN
  - Westrup USA - Dallas, TX
  - Satake USA – Stafford, TX
  - Seedburo – Chicago, IL
  - Universal Industries - Cedar Falls, IA

**Thanks for your continued support for the ISU Seed Conditioning Program**