Optimizing Brewed Coffee Quality Through Proper Grinding

Daniel Ephraim
President
Modern Process Equipment
Is there a particular grinding problem or issue that you would like to see addressed today?

THERE’S NOTHING WORSE THAN SITTING THROUGH A PRESENTATION AND WALKING AWAY “EMPTY HANDED”!
Presentation Outline

• The Coffee Quality Cycle
• Brewing Theory:
  – Key factors in Coffee Brewing or Extraction:
    • Particle size
    • Particle uniformity
    • Time
  – The “Big Picture” in Coffee Brewing
• Effect of Temperature on Ground Coffee
• Analyzing and Testing Ground Coffee
• Grinding for Pods and Espresso Coffee

Questions and Discussions
Proper coffee grinding is a most essential, and often neglected, part of the coffee quality process.

So let’s explore the process from the beginning with selected coffee quality tipping points ...
Theoretical Coffee Quality = 100%

Maximum Possible Coffee Beverage Quality = 100%
We cannot improve on Mother Nature!
Coffee Processing

Tipping Point

Poor Preparation

Quality Decreases
Coffee Transportation

Exposure to Adverse Conditions

Tipping Point

Quality Decreases
Coffee Roasting

Tipping Point

Over/Under Roasted

Quality Decreases
Improper Grind Size/Poor Uniformity

Tipping Point

Quality decreases, including the value of all processes up to this point

Coffee Grinding
Theoretical Coffee Quality = 100%

Maximum Possible Coffee Beverage Quality = 100%

The Coffee Quality Cycle

Tree

Cup

Processing

Brewing

Transportation

Grinding

Warehouse

Roasting
The great thing about cupping coffee is that it pretty well defines the quality of the bean.
BUT, the tough part is grinding the coffee to achieve the same quality of the bean to the brew.
We don’t brew whole bean coffee!
Proper Extraction and Strength

Coffee beans are composed of soluble solids, which must be extracted into the coffee brew.
Proper Extraction and Strength

The amount of soluble solids extracted from the coffee bean into the brew must be the correct amount or percentage.
This is a much magnified view of a ground coffee particle using an electron microscope.

The cellular walls are about 30 microns in diameter, and the colloidal material fills the voids within the ground coffee and cellular structures. Part of this colloidal material is what we want to extract, but with a limit.
Proper Extraction and Strength

Ideal Extraction of the coffee particle’s soluble solids is 18-22%

Ideal Brew Strength is 1.15-1.35% brewed solids
One Example of Overextraction is Turkish Coffee

... Where the entire bean is ground and dissolved into hot water.

... Excess solids settle on the bottom of the cup, which is typically considered undrinkable.
The Center of the Universe for Coffee Grinding is EXTRACTION! Specifically ... PROPER EXTRACTION!

The key to PROPER EXTRACTION is creating, through GRINDING, the ideal exposed coffee surface areas.
Effect of Grind Size on Surface Area

1 Bean = 3.4 cm$^2$

2 Particles = 4.4 cm$^2$

4 Particles = 5.4 cm$^2$

1000 Particles = 34 cm$^2$
Grind Comparison

- 100 – 300 particles
  - French Press, Coarse
- 500 – 800 particles
  - Drip, Filter
- 1,000 – 3,000 particles
  - Vending, Filter Fine
- 3,500 particles
  - Espresso
- 15,000 – 35,000 particles
  - Turkish

Legend

= One Coffee Bean
Grind Sizes

• Typically expressed in:
  – Mesh
  – Microns (um)

25,400 microns = 1 inch

or

100 microns = 0.004 Inch = Thickness of One Hair!
Average Particle Size by Grind

Average Size in Microns

E.P.  Urn  ADC  Drip  Fine  Pod  Vending  Espresso Medium  Espresso Fine  Turkish-Coarse  Turkish-Fine
Average Size vs. Surface Area
(1 Bean = 3.4 cm² = Size of a Postage Stamp)

Surface Area Increases as Brewing Time Decreases!
**Micro Analysis of Extraction**

600 particles (850 um avg.)

1 particle

Ideal Grind Size (drip)

H₂O

4 min. brew cycle

RESULT:

20%

Ideal Extraction (Good Taste)
Micro Analysis of Extraction

600 particles (850 um avg.)

Factors:
1) Time is consistent.
2) Particle size has decreased.

Result:
Since the coffee particle is smaller than ideal, the surface area is greater and the extraction rate will be excessive.

RESULT:
30% Overextraction (Poor/Bitter Taste)
Micro Analysis of Extraction

Conclusion #1:

Ideal extraction is a function of proper particle size for the brew time.
The Importance of Grind Uniformity

Typical Ground Coffee Particle Size

24,500 microns = 1 inch

The Importance of Grind Uniformity

Average Size in Microns

Particle Size

E.P.  Regular  ADC  Drip  Fine  Espresso Coarse  Espresso Medium  Vending  Espresso Fine  Turkish-Coarse  Turkish-Fine
The Importance of Grind Uniformity

Typical Ground Coffee Particle Size

24,500 microns = 1 inch
Grind Uniformity Comparison

Non-Uniform Particle Size

Uniform Particle Size
Uniform vs. Non-Uniform Coffee Grind

Poor Quality, Non-Uniform, Coffee Grind

Ideal, Uniform Coffee Grind

% Retained (Non-Cumulative)

Oversize

Desired Size

Undersize
Roller vs. Disc Grinder

% Retained (Non-Cumulative)

Oversize  Desired Size  Undersize

Roller Grinder

Disc Grinder
Impact of Improper Grinding Practice on Grind Quality
(Poor Methodology, Excessive Wear, etc.)

% Retained (Non-Cumulative)

Oversize

Desired Size 650 um

Undersize

645 um/1.35 σ

650 um/ 3.0 σ

Uniform ground coffee distribution (good)

Non-uniform ground coffee distribution (bad)
Micro Analysis of Extraction

- **Ideal Grind Size (drip)**
- **600 particles (850 um avg.)**
- **4 min. brew cycle**
- **RESULT:**
  - 20% Ideal Extraction (Good Taste)
Micro Analysis of Extraction

Ideal Grind Size (drip)

Factors:
1) Time is consistent.
2) Particle uniformity is inconsistent.

RESULT:
30% Overextraction (Poor/Bitter Taste)

RESULT:
20% Ideal Extraction (Good Taste)

RESULT:
Underextraction (Tea-Like Taste)

Result:
Since some of the coffee particles are smaller and larger than ideal, the surface areas are greater and lesser and the extraction rates will be excessive or insufficient.
Micro Analysis of Extraction

Conclusion #2:

Ideal extraction is a function of proper particle size uniformity.
Optimal Brew Time vs. Particle Size

Brew Time vs. Particle Size to Achieve 20% Extraction Rate

Particle Size Dictates Brew Time! Brew Time Dictates Particle Size!
Effect of Extraction Time on Taste

Cumulative Chemical Composition of Brewed Coffee with Increased Extraction Time

The overextraction of brewed coffee (beyond the recommended brewing time) leads to the incorporation of undesirable and less soluble aromatic compounds into the drink (printed in blue).

<table>
<thead>
<tr>
<th>Compound</th>
<th>Aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>2, 4-decadienal</td>
<td>RANCID</td>
</tr>
<tr>
<td>ethylguajacol</td>
<td>SMOKE</td>
</tr>
<tr>
<td>2-ethyl-3,5-dimethylpyrazine</td>
<td>CHOCOLATE</td>
</tr>
<tr>
<td>2-ethyl-3,6-dimethylpyrazine</td>
<td>CHOCOLATE</td>
</tr>
<tr>
<td>2, 4-nonadienal</td>
<td>RANCID</td>
</tr>
<tr>
<td>methylsalicylate</td>
<td>CINNAMON</td>
</tr>
<tr>
<td>b-damascenone</td>
<td>TEA</td>
</tr>
<tr>
<td>DMTS</td>
<td>SULFUR</td>
</tr>
<tr>
<td>isovaleraldehyde</td>
<td>SWEET</td>
</tr>
<tr>
<td>a-ionone</td>
<td>FLOWERS</td>
</tr>
<tr>
<td>linalool</td>
<td>FLOWERS</td>
</tr>
</tbody>
</table>
Effect of Cycle Time on Taste

 Courtesy of the Coffee Brewing Center
Micro Analysis of Extraction

600 particles (850 um avg.)

H₂O

4 min. brew cycle

RESULT:
20%
Ideal Extraction
(Good Taste)

Ideal Grind Size (drip)
**Micro Analysis of Extraction**

**Ideal Grind Size (drip)**

- 600 particles (850 um avg.)
- 8 min. brew cycle
- 850 um

**Factors:**
1) Particle size is consistent.
2) Time has changed.

**Result:**
Since the brewing time is too long for the relative particle size, the extraction rate is excessive.

**RESULT:**
30-35% Overextraction (Poor/Bitter Taste)
Macro Analysis of Extraction

Espresso Brewer
225 um grind

H₂O
20 sec.

Optimum Brew
Macro Analysis of Extraction

Espresso Brewer

*225 um grind*

H2O

20 sec.

H2O

1 min.

Optimum Brew

Over Extracted Brew
Macro Analysis of Extraction

Espresso Brewer
- 225 um grind
- 20 sec.
- Over Extracted Brew
- Optimum Brew

Filter Basket Brewer
- 850 um grind
- 1 min.
- 4 min.
- Over Extracted Brew
- Optimum Brew
Macro Analysis of Extraction

**Espresso Brewer**
225 um grind

- 20 sec.
- 1 min.

**Filter Basket Brewer**
850 um grind

- 4 min.
- 2 min.

Optimum Brew

Over Extracted Brew

Under Extracted Brew
Macro Analysis of Extraction

**Espresso Brewer**
- 225 um grind
- 20 sec.
- 1 min.

**Filter Basket Brewer**
- 850 um grind
- 4 min.
- 2 min.
- 8 min.

- **Over Extracted Brew**
- **Under Extracted Brew**
- **Optimum Brew**
- **Over Extracted Brew**

*850 um grind*
Micro Analysis of Extraction

Conclusion #3:

Ideal extraction is a function of proper brew time for the method and grind.
Macro Grind Challenge

64 oz. H2O

Extract for 4 min.

3.75 oz.

Good Grind Goal: 20% extraction of soluble solids

Approx. 6 oz. water retention in grounds

58 oz. liquid (64 oz. – 6 oz.)

Soluble Solids: 1.3% (0.75 oz./58 oz.)

20% * 3.75 = .75 oz.
The “Gold Cup” Standard Calculation

How do we calculate brewed solids?

1. Use 64 oz. of water for brewing
2. Subtract water absorbed in coffee grounds (6 fl/oz.)
3. Use 3.75 oz. of ground coffee to extract 20% solids
4. Brew to “Gold Cup” Standard that will extract 20% of solids: 
   \[ 20\% \times 3.75 \text{ oz.} = 0.75 \text{ oz.} \]
5. Calculate brewed solids as percentage of liquid:
   \[ 0.75 \text{ oz.}/58 \text{ oz.} = 1.3\% \]
Evaluation of the **same grind** (average particle size) but different uniformities

Particle Size/Particle Uniformity:

- **645 um/1.35 \( \sigma \) (Good Quality Grind)**
- **650 um/ 3.0 \( \sigma \) (Poor Quality Grind)**
The Key Principals of Coffee Extraction

• The rate of soluble solids extraction from a coffee particle is directly related to the amount of exposed surface area to the hot water.

• The time that the hot water will be exposed to the coffee particle must be directly proportional to the exposed surface area, or particle size, of the ground coffee.

• If particle size, uniformity and brewing time are matched correctly, with all other factors being equal, a 20% extraction rate can be achieved.
Ideal Matrix of Grind vs. Time

Brewed Coffee Taste Profiles

- Excessive Brew Times:
  - Coarse Grind: Under-Developed
  - Optimal Grind: Under-Developed
  - Fine Grind: Under-Developed

- Optimal Brew Times:
  - Coarse Grind: Under-Developed
  - Optimal Grind: Optimum Balance
  - Fine Grind: Weak Under-Developed

- Too Short Brew Times:
  - Coarse Grind: Under-Developed
  - Optimal Grind: Weak
  - Fine Grind: Weak Under-Developed

- Grind and Brew Time Combinations:
  - Optimum Balance: Strong
  - Strong Bitter: Strong
  - Bitter: Under-Developed
  - Weak Bitter: Weak
Ideal Matrix of Grind vs. Time

**Brewed Coffee Taste Profiles**

- **Weak**
  - Under-Developed
  - Strong Under-Developed
  - Weak Under-Developed

- **Strong**
  - Under-Developed
  - Optimum Balance
  - Weak

- **Bitter**
  - Excessive
  - Optimal
  - Too Short

- **Most Common Problems**
  - Strong Bitter
  - Optimum Balance
  - Weak Bitter
**Goal:**
We only want to roast coffee once, and that is in the roaster!

**Challenge:**
Maintain low temperatures during grinding.

= **OK!**

= **NOT OK!**
## Chemical Composition of Coffee Volatiles and Aromatics

### Aldehydes

<table>
<thead>
<tr>
<th>Aldehyde</th>
<th>mass (amu)</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propanal</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>n-Butanal</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>Isobutanal</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Isopentanal</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>2-Methylbutanal</td>
<td>137</td>
<td>137</td>
</tr>
<tr>
<td>n-Hexanal</td>
<td>151</td>
<td>151</td>
</tr>
<tr>
<td>2-Methylhex-2-enal</td>
<td>172</td>
<td>172</td>
</tr>
<tr>
<td>Benzaldehyde</td>
<td>112</td>
<td>112</td>
</tr>
<tr>
<td>O-Toluic acid</td>
<td>112</td>
<td>112</td>
</tr>
<tr>
<td>Salicylic acid</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>Phenylacetaldehyde</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>3-Methyl-2-butenal</td>
<td>133</td>
<td>133</td>
</tr>
</tbody>
</table>

### Substances with vapor pressures below 500 mm. Hg. at 20°C.

- Methyl formate
- Methyl acetate
- Methyl propionate
- Methyl butyrate
- Methyl hexanoate
- Benzyl formate
- y-Butyrolactone
- Crotonaldehyde
- Acetal acetate
- Butan-2-one-1-yl acetate
- n-Butyl acetate
- Isoamyl formate
- Isobutyl acetate
- Methyl phenylacetate
Temperature Rise During Grinding

- **High Temperature/Vapor Pressure**
  - Flavors and Aromatics
  - Coffee Darkens

- **Medium Temperature/Vapor Pressure**
  - Flavors and Aromatics

- **Low Temperature/Vapor Pressure**
  - Flavors and Aromatics

---

Disc-Style Coffee Grinder w/o Water-Cooling

Increasing Loss of Flavors & Aromatics

Coffee Darkens
Temperature Rise During Grinding

- **Disc-Style Coffee Grinder w/ Water-Cooling**
- **Disc-Style Coffee Grinder w/o Water-Cooling**

Coffee Temperature (Deg F) vs. Grinder Run Time (Minutes)

- **High Temperature/Vapor Pressure**
- **Medium Temperature/Vapor Pressure**
- **Low Temperature/Vapor Pressure**

Increasing Loss of Flavors & Aromatics

Coffee Darkens
One Example of the Results from a Water-Cooled Disc-Style Grinder

Model GPX.WCI (Water-Cooling Integrated)
Disc-Style Coffee Grinder
Questions?
Is Evaluating Ground Coffee “By Eye” Reliable?
What do you see?
What do you see?
Which Line is Longer?
Which Line is Longer?
Which Line is Longer?
Which Line is Longer?
Which Line is Longer?
They’re the same length.
Which box is bigger?
They’re both the same size.
Is this line straight?
Nope.
Which grind is smaller?

This one.
Analyzing and Testing Ground Coffee
The Ro-Tap Method
The Ro-Tap Method

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>Oversize</th>
<th>Desired Size</th>
<th>Undersize</th>
<th>Pan</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Retained (Non-Cumulative)</td>
<td>10</td>
<td>14</td>
<td>20</td>
<td>28</td>
</tr>
</tbody>
</table>

Diagram showing the distribution of % retained size categories.
The Ro-Tap Method

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>10</th>
<th>14</th>
<th>20</th>
<th>28</th>
<th>Pan</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Retained (Non-Cumulative)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oversize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Desired Size</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undersize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MESH (Tyler)</th>
<th>Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td></td>
</tr>
</tbody>
</table>
The Ro-Tap Method

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>Oversize</th>
<th>Desired Size</th>
<th>Undersize</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>14</td>
<td>20</td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MESH (Tyler)</th>
<th>Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>14</td>
<td>4.4</td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td></td>
</tr>
</tbody>
</table>
The Ro-Tap Method

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>10</th>
<th>14</th>
<th>20</th>
<th>28</th>
<th>Pan</th>
</tr>
</thead>
<tbody>
<tr>
<td>MESH (Tyler)</td>
<td>Weight (grams)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>4.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>28.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>PAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Ro-Tap Method

Screen Size

<table>
<thead>
<tr>
<th>Size</th>
<th>MESH (Tyler)</th>
<th>Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>28.9</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>42.2</td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% Retained (Non-Cumulative)

Oversize    Desired Size    Undersize
The Ro-Tap Method

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>10</th>
<th>14</th>
<th>20</th>
<th>28</th>
<th>Pan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MESH (Tyler)</th>
<th>Weight (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
</tr>
<tr>
<td>14</td>
<td>4.4</td>
</tr>
<tr>
<td>20</td>
<td>28.9</td>
</tr>
<tr>
<td>28</td>
<td>42.2</td>
</tr>
<tr>
<td>PAN</td>
<td>23.9</td>
</tr>
</tbody>
</table>
### Ro-Tap Calculation

**NOTES**

<table>
<thead>
<tr>
<th>MESH (Tyler)</th>
<th>grams</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6</td>
<td>0.6%</td>
</tr>
<tr>
<td>14</td>
<td>4.4</td>
<td>4.4%</td>
</tr>
<tr>
<td>20</td>
<td>28.9</td>
<td>28.9%</td>
</tr>
<tr>
<td>28</td>
<td>42.2</td>
<td>42.2%</td>
</tr>
<tr>
<td>PAN</td>
<td>23.9</td>
<td>23.9%</td>
</tr>
</tbody>
</table>

**TEST #**

**DATE:**

25-Apr-03

Fine Drip Grind Sample
Ro-Tap Graph

Screen Size (Tyler Mesh) vs % Retained (Non-Cumulative)

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>Drip Grind</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>0.6%</td>
</tr>
<tr>
<td>14</td>
<td>4.4%</td>
</tr>
<tr>
<td>20</td>
<td>28.9%</td>
</tr>
<tr>
<td>28</td>
<td>42.2%</td>
</tr>
<tr>
<td>PAN</td>
<td>23.9%</td>
</tr>
</tbody>
</table>
Laser Particle Size Analysis
Principle of Laser Particle Size Analysis
Laser Analysis Results

Result: Sieve ASTM E11-61 Table

<table>
<thead>
<tr>
<th>Mesh No</th>
<th>Aperture (µm)</th>
<th>Volume In%</th>
<th>Volume Below%</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2000</td>
<td>100.00</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1680</td>
<td>99.86</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>1410</td>
<td>99.55</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1190</td>
<td>98.72</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>1000</td>
<td>98.22</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>841</td>
<td>93.23</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>707</td>
<td>85.97</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>595</td>
<td>75.27</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>500</td>
<td>55.69</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>420</td>
<td>35.22</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>354</td>
<td>20.27</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>297</td>
<td>8.47</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>250</td>
<td>3.44</td>
<td></td>
</tr>
</tbody>
</table>

Conc. = 0.3076 %
Vol Density = 1.000 g/cm³
S.S.A. = 0.0144 m²/g
Span = 9.760E-01

D(v,0.1) = 306 µm  10% Percentile
D(v,0.5) = 478 µm  Average Particle Size
D(v,0.9) = 772 µm  90% Percentile
Two Different Fine Grinds

Average Particle Sizes are the same.

Brew Qualities are different!
The MPE Single Sieve “Hand” Ro-Tap Method

Use about 50 grams

24 mesh/700 um screen size

Pan

Shake and rotate for five minutes, occasionally tapping on a table

Use Single Sieve chart to determine the average particle size by referencing the percentage of coffee retained on the sieve.

Percentage Above

Percentage Below
Weigh your results using a portable scale.

The MPE Single Sieve “Hand” Ro-Tap Method
The MPE Single Sieve Reference Chart
Disc-Style Coffee Grinder

Sample result was 50% retained on top of 24 Mesh screen

Calculated Particle size: 700 um

Note: Use Roller-Style Reference Chart for Roller-Style Coffee Grind Results

Copyright MPE, 2009
The MPE Single Sieve Reference Chart
Disc-Style Coffee Grinder

Sample result was 60% retained on top of 24 Mesh screen

Calculated Particle size: 800 um

Note: Use Roller-Style Reference Chart for Roller-Style Coffee Grind Results

Copyright MPE, 2009
Size Conversion and Grind Reference Table

<table>
<thead>
<tr>
<th>U.S. Mesh</th>
<th>Tyler Mesh</th>
<th>Inches</th>
<th>Microns</th>
<th>Grind*</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>4</td>
<td>0.1850</td>
<td>4699</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>0.1560</td>
<td>3962</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0.1310</td>
<td>3327</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>0.1100</td>
<td>2794</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>0.0930</td>
<td>2362</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>9</td>
<td>0.0780</td>
<td>1981</td>
<td>Extract Grinds and French Press</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>0.0650</td>
<td>1651</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>0.0550</td>
<td>1397</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>14</td>
<td>0.0460</td>
<td>1168</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>16</td>
<td>0.0390</td>
<td>991</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>20</td>
<td>0.0328</td>
<td>833</td>
<td>Drip Grind</td>
</tr>
<tr>
<td>25</td>
<td>24</td>
<td>0.0276</td>
<td>701</td>
<td>Fine Grind</td>
</tr>
<tr>
<td>30</td>
<td>28</td>
<td>0.0232</td>
<td>589</td>
<td>Euro Filter Fine</td>
</tr>
<tr>
<td>40</td>
<td>35</td>
<td>0.0195</td>
<td>495</td>
<td>Espresso Coarse</td>
</tr>
<tr>
<td>45</td>
<td>42</td>
<td>0.0138</td>
<td>351</td>
<td>Vending</td>
</tr>
<tr>
<td>50</td>
<td>48</td>
<td>0.0116</td>
<td>295</td>
<td>Espresso Fine</td>
</tr>
<tr>
<td>60</td>
<td>60</td>
<td>0.0097</td>
<td>246</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>65</td>
<td>0.0082</td>
<td>208</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>80</td>
<td>0.0069</td>
<td>175</td>
<td>Coarse Turkish</td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>0.0058</td>
<td>147</td>
<td>Medium Turkish</td>
</tr>
<tr>
<td>120</td>
<td>115</td>
<td>0.0049</td>
<td>124</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>150</td>
<td>0.0041</td>
<td>104</td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>170</td>
<td>0.0035</td>
<td>89</td>
<td>Fine Turkish</td>
</tr>
<tr>
<td>200</td>
<td>200</td>
<td>0.0029</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>250</td>
<td>0.0024</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>270</td>
<td>270</td>
<td>0.0021</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>325</td>
<td>325</td>
<td>0.0017</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>400</td>
<td>0.0015</td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

Available online at: www.mpechicago.com/coffee

* = Average Particle Size
Segregation

Once coffee is ground, care must be taken so that the particles don’t “declassify” between the grinder and the package, pod or other delivery container.
Segregation

Segregation Video

Courtesy of Jenike and Johanson, Inc.
Espresso and Single-Cup Serving methods are the toughest grinds to achieve!
Brewer Examples

Flavia
- Flavia Filter Pack

Keurig
- Keurig K Cup

Tassimo
- Tassimo T-Discs
Filter-Type Packages
... or shaped like these
<table>
<thead>
<tr>
<th>Brewing Dynamics</th>
<th>1 Pod/8 oz. cup</th>
<th>Equivalent Coffee Pack for 64 oz. Brew</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee Weight</td>
<td>9 grams</td>
<td>3.75 oz.</td>
<td>1/12th the weight</td>
</tr>
<tr>
<td>Water Pressure (psi)</td>
<td>10 – 70</td>
<td>Gravity: 0.1 – 0.5</td>
<td></td>
</tr>
<tr>
<td>Brew Time</td>
<td>10 – 15 sec.</td>
<td>3 – 6 min.</td>
<td></td>
</tr>
<tr>
<td>Grind Size (microns)</td>
<td>400 - 600</td>
<td>800 – 900</td>
<td></td>
</tr>
</tbody>
</table>
# Pod vs. Fresh Brew Performance Comparison

<table>
<thead>
<tr>
<th>Brewing Dynamics</th>
<th>1 Pod/8 oz. cup</th>
<th>Equivalent Coffee Pack for 64 oz. Brew</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee Weight</td>
<td>9 grams</td>
<td>3.75 oz.</td>
<td>1/12th the weight</td>
</tr>
<tr>
<td>Water Pressure (psi)</td>
<td>10 – 70</td>
<td>Gravity: 0.1 – 0.5</td>
<td>130 times the water pressure</td>
</tr>
<tr>
<td>Brew Time</td>
<td>10 – 15 sec.</td>
<td>3 – 6 min.</td>
<td></td>
</tr>
<tr>
<td>Grind Size (microns)</td>
<td>400 - 600</td>
<td>800 – 900</td>
<td></td>
</tr>
</tbody>
</table>
## Pod vs. Fresh Brew Performance Comparison

<table>
<thead>
<tr>
<th>Brewing Dynamics</th>
<th>1 Pod/8 oz. cup</th>
<th>Equivalent Coffee Pack for 64 oz. Brew</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee Weight</td>
<td>9 grams</td>
<td>3.75 oz.</td>
<td>1/12th the weight</td>
</tr>
<tr>
<td>Water Pressure (psi)</td>
<td>10 – 70</td>
<td>Gravity: 0.1 – 0.5</td>
<td>130 times the water pressure</td>
</tr>
<tr>
<td>Brew Time</td>
<td>10 – 15 sec.</td>
<td>3 – 6 min.</td>
<td>1/20th the time</td>
</tr>
<tr>
<td>Grind Size (microns)</td>
<td>400 - 600</td>
<td>800 – 900</td>
<td></td>
</tr>
</tbody>
</table>
## Pod vs. Fresh Brew Performance Comparison

<table>
<thead>
<tr>
<th>Brewing Dynamics</th>
<th>1 Pod/8 oz. cup</th>
<th>Equivalent Coffee Pack for 64 oz. Brew</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coffee Weight</td>
<td>9 grams</td>
<td>3.75 oz.</td>
<td>1/12th the weight</td>
</tr>
<tr>
<td>Water Pressure (psi)</td>
<td>10 – 70</td>
<td>Gravity: 0.1 – 0.5</td>
<td>130 times the water pressure</td>
</tr>
<tr>
<td>Brew Time</td>
<td>10 – 15 sec.</td>
<td>3 – 6 min.</td>
<td>1/20th the time</td>
</tr>
<tr>
<td>Grind Size (microns)</td>
<td>400 - 600</td>
<td>800 – 900</td>
<td>1/2 the grind size</td>
</tr>
</tbody>
</table>
A pod grind is one of the most technical and challenging grinds, yet is typically produced on the most basic, limited grinder as a matter of convenience.

The grind must be the correct size and uniformity to produce a comparable coffee brew!
Now let’s take a closer look at Espresso Grinding:

Two apparently contradictory needs must be satisfied to prepare a good cup of espresso:

1) On the one hand, a short percolation time is required;
2) On the other hand, a high concentration of soluble solids must be reached.
Both requirements can only be attained if a close contact between solid particles and extraction water can be achieved.

Thus, espresso percolation needs a plurimodal particle size distribution, where the finer particles enhance the exposed extraction surface (chemical need) and the coarser ones allow the water flow (physical need).
Let’s look at an espresso particle distribution using an electron microscope.

Upon further magnification, we can see the cellular structure and hexagonal structure in more detail, as well as the “fines” which are an essential and integral part of espresso grinding.

We can also see the rupture of the cellular walls, which are 30 um in diameter, which is the same size as the “superfines” that are a required element in espresso grinding.
Ideal Espresso Grinding

*It is typically desirable to generate “fines” (20-40 um) when grinding for espresso to promote the proper infusion.*
Basic Illustration of Bimodal/Plurimodal Concept

Target

Bimodal Grind

Traditional Grind
How do you determine the optimal grind for your application?

1) Use a grind reference document (SCAA, MPE, etc.) to determine the correct grind for your application or, alternatively:

2) Perform a grind test using the ro-tap, hand ro-tap or laser method to ensure that your actual grind matches your target.

3) In conjunction with the above, utilize a soluble solids tester* to establish:
   - Your brewed solids and;
   - Your desired grind to achieve or maintain those brewed solids.

* Either a hydrometer or soluble solids “Ultrameter” can be used for the above.
Questions?
Enjoy the show!