Analyzing Coffee Carbohydrates

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Outline

• Why do we need to determine coffee carbohydrates?

• Experiences with AOAC Official Method 995.13

• Fast Method
Key Messages

• Why do we need to determine coffee carbohydrates?
  • Flavor, authenticity, global coffee market

• AOAC Official Method 995.13
  • Long, 80-min run time
  • Two sugar pairs difficult to resolve
  • Recommendations proposed

• Fast Method
  • Run time 8 min
  • Two sugar pairs not resolved
Coffee Preparation: Bean to Brew
“It is difficult to imagine a world without coffee.”

- Legend of Its Origins: Yemen goat herder story
- Botanical Studies: Ethiopia → Yemen (6th century)
- Arab World → Europe → America

- Coffee berries produced by several species of small evergreen bush of the genus *Coffea*
  - *Coffea arabica*
  - *Coffea canephora* (robusta)

- Five years for a coffee plant to start bearing fruit (cherries)
Five Steps to a Cup of Coffee

**Drying**
Green coffee beans are dried from a moisture level of 53% to 12% via sun-drying or machines. Hulls are removed by mechanical means and the beans are graded.

**Blending**
Manufacturers blend beans to achieve the unique flavor of their brand.

**Roasting**
Time, Temperature, and Humidity—manufacturers usually roast beans for five minutes at gas temperatures of 260 ºC.

**Grinding**
Average particle size affects the properties of the coffee when brewed, brewing time, and storage stability.

**Brewing**
Many variables influence the process of brewing—particle size, proportions of coffee and water, water temperature, the mixing mechanism of the brewing equipment, and brewing time.

*Each step affects the carbohydrate profile.*
Economics of Coffee Consumption

- Ranks second only to petroleum in terms of dollars traded
- One of the most traded agricultural commodity
- 6.3 million tons produced worldwide
- Over 2.25 billion cups of coffee/day consumed
- Brazil, Vietnam, Columbia (over 70 countries grow coffee)

\[ r: \text{Coffea robusta} \]
\[ m: \text{Coffea robusta and Coffea arabica.} \]
\[ a: \text{Coffea arabica} \]
The International Coffee Agreement (ICA) is an international commodity agreement to achieve a reasonable balance between the supply and demand of coffee.
History of Instant Coffee

1771: Patent application for instant coffee (England)

1901: S. Kato (Japan)

1906: Commercial production (U.S.)
   • Concentrated coffee → evaporate the water to leave a soluble, dry coffee mix
   • Convenient, quick to make, easy to carry, and increased shelf life
   • The problem, of course, was taste…………

1930: Nestle’s Nescafe
Nescafe began mixing soluble carbohydrates with concentrated coffee before drying.

1960: Maxwell House introduced freeze-dried instant coffee.

Today: The global instant coffee market is estimated to be at a hefty $21 billion per year.

Nestle and Nescafe are registered trademarks of Société des Produits Nestlé S.A. and Maxwell House is a registered trademark of Kraft Foods Global Brands LLC.
Green coffee beans: twice stronger antioxidant effect than green tea and grape seed extract.

Starbucks Eyes Expansion of Cold Beverage Line
Green Coffee “Refreshers” Test Starts Aug. 4

“Ingredients include a ‘flavor neutral’ powdered extract made from unroasted green coffee and formulated to have less of a caffeine kick than regular coffee.”

Coffee Carbohydrates

- Provide the flavor of coffee
- Constitute the major part (at least 50% of the dry weight) of raw coffee beans
- Contain aroma binders
- Are foam stabilizers
- Impart viscosity
- Are very good tracers for the authenticity of instant coffee

Tests Done on Green and Roasted Coffee

Bean Density
Brightness
Titratable Acidity
pH
Moisture
Total Soluble Solids

Caffeine
Chlorogenic Acids
Lipids
Carbohydrates

Green Coffee (sucrose contributes to formation of aroma)
Total Polyphenols
Total Proteins
Ochratoxin A, Aflatoxins (AOAC Method)
Experimental Details

- **Eluent Generator (Hydroxide)**
- **High-Pressure Nonmetallic Pump**
- **Sample Inject (Autosampler)**
- **Separation Column**
- **Detection Electrochemical Detector**
- **Data Management**

**Materials:**
- $\text{H}_2\text{O}$
Chromatographic Conditions

AOAC Method 995.13

Columns: Thermo Scientific™ Dionex™ CarboPac™ PA1, Guard & Analytical set

Eluent: DI water, and 300 mM base for column wash and postcolumn delivery

Flow Rate: 1.0 mL/min

Inj. Volume: 10 µL (Full Loop)

Temp: 25 ºC

Detection: PAD (Au)
AOAC Method 995.13: Carbohydrates in Soluble Coffee

- Carbohydrates are separated on a pellicular ion-exchange column and measured by pulsed amperometric detection (PAD).

- Sample Preparation

  **Free Carbohydrates**
  - Coffee is dissolved in $\text{H}_2\text{O}$
  - Solution is filtered through C18 disposable cartridge, and then through 0.2 µm membrane filter

  **Total Carbohydrates**
  - Coffee is hydrolyzed with 1M HCl
  - Solution is filtered and then passed through a cation-exchange disposable cartridge to neutralize the solution and to eliminate the Cl anion prior to injection
AOAC Method 995.13

Table 995.13K. Conditions of mobile phase for determination of free and total carbohydrates in soluble coffee by anion-exchange chromatographic method with pulsed amperometric detection

<table>
<thead>
<tr>
<th>Time, min</th>
<th>Eluent A, %</th>
<th>Eluent B, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>0 (start acquisition)</td>
</tr>
<tr>
<td>50.0</td>
<td>100</td>
<td>0 (stop acquisition)</td>
</tr>
<tr>
<td>50.1</td>
<td>0</td>
<td>100 (start cleanup)</td>
</tr>
<tr>
<td>65.0</td>
<td>0</td>
<td>100 (stop cleanup)</td>
</tr>
<tr>
<td>65.1</td>
<td>100</td>
<td>0 (start re-equilibrium)</td>
</tr>
<tr>
<td>80.0</td>
<td>100</td>
<td>0 (stop re-equilibrium)</td>
</tr>
</tbody>
</table>
Results
Mixed Carbohydrate Standard on a Dionex CarboPac PA1 AOAC Method 995.13

Peaks:
1. Mannitol 14 mg/L
2. Fucose 15
3. Rhamnose —
4. Arabinose —
5. Galactose 53
6. Glucose 55
7. Sucrose —
8. Xylose —
9. Mannose 48
10. Fructose 93
11. Ribose 97

Column: Dionex CarboPac PA1
Eluent: DI water from 0 to 50 min, 300 mM NaOH from 50 to 65 min, DI water from 65 to 80 min (re-equilibration)
Flow Rate: 1.0 mL/min
Inj. Volume: 10 µL
Temp: 25 ºC
Detection: PAD (Au)
Known Issues and AOAC’s Recommendations

• “If resolution of rhamnose from arabinose is difficult to achieve, do not add rhamnose to mixed standard solution.”

• “It may be necessary to perform 2–3 injections of carbohydrates standard solution or to increase the re-equilibrium time in order to achieve a good separation of glucose, sucrose, and xylose.”

• From our work we have developed two recommendations.
Recommendation #1: Lower Temperature

**Column:** Dionex CarboPac PA1

**Eluent:** DI water

**Flow Rate:** 1.0 mL/min

**Inj. Volume:** 10 µL

**Temp:** 15°C

**Detection:** PAD (Au)

**Peaks:**
1. Mannitol 14 mg/mL
2. Fucose 15
3. Arabinose 39
4. Rhamnose 39
5. Galactose 53
6. Glucose 55
7. Xylose 57
8. Sucrose 52
9. Mannose 38
10. Fructose 93
11. Ribose 97
Recommendation #1: Applied to Coffee Analyses

A. Standards
B. Free Carbohydrates in Green Coffee
C. Free Carbohydrates in Instant Coffee
D. Total Carbohydrates in Instant Coffee

Peaks:
1. Mannitol
2. Fucose
3. Arabinose
4. Rhamnose
5. Galactose
6. Glucose
7. Xylose
8. Sucrose
9. Mannose
10. Fructose
11. Ribose

Column: Dionex CarboPac PA1
Eluent: DI water from 0 to 50 min,
300 mM NaOH from 50 to 65 min,
DI water from 65 to 80 min (re-equilibration)
Flow Rate: 1.0 mL/min
Inj. Volume: 10 µL
Temp: 15°C
Detection: PAD (Au)
## Precision: AOAC Method for Mixed Carbohydrate Standard

### Recommendation #1: 15 °C

<table>
<thead>
<tr>
<th>Carbohydrate</th>
<th>Concen for Precision Injection (mg/mL)</th>
<th>Retention Time Precision (RSD)</th>
<th>Peak Area Precision (RSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>15</td>
<td>0.20</td>
<td>4.49</td>
</tr>
<tr>
<td>Fucose</td>
<td>15</td>
<td>0.24</td>
<td>4.69</td>
</tr>
<tr>
<td>Rhamnose</td>
<td>35</td>
<td>0.40</td>
<td>4.83</td>
</tr>
<tr>
<td>Arabinose</td>
<td>40</td>
<td>0.30</td>
<td>4.66</td>
</tr>
<tr>
<td>Galactose</td>
<td>50</td>
<td>0.42</td>
<td>4.72</td>
</tr>
<tr>
<td>Glucose</td>
<td>55</td>
<td>0.46</td>
<td>4.82</td>
</tr>
<tr>
<td>Sucrose</td>
<td>45</td>
<td>0.68</td>
<td>5.15</td>
</tr>
<tr>
<td>Xylose</td>
<td>55</td>
<td>0.42</td>
<td>4.88</td>
</tr>
<tr>
<td>Mannose</td>
<td>45</td>
<td>0.44</td>
<td>4.87</td>
</tr>
<tr>
<td>Fructose</td>
<td>90</td>
<td>0.47</td>
<td>4.45</td>
</tr>
<tr>
<td>Ribose</td>
<td>90</td>
<td>0.48</td>
<td>4.66</td>
</tr>
</tbody>
</table>

*n = Six Injections*
Recommendation #2a (for Instant Coffee)

- 10 mM Base for 6 min, other parameters same as AOAC Method.
- Do not include sucrose in mix of standards.

Peaks:
1. Mannitol 15 mg/L
2. Fucose 15
3. Rhamnose 35
4. Arabinose 40
5. Galactose 50
6. Glucose 55
7. Xylose 55
8. Mannose 45
9. Fructose 90
10. Ribose 90

Column: Dionex CarboPac PA1
Eluent: 10 mM NaOH 0–6 min, DI water 6–50 min, 300 mM NaOH from 50 to 65 min, DI water from 65 to 80 min (re-equilibration)
Flow Rate: 1.0 mL/min
Inj. Volume: 10 µL
Temp: 25°C
Detection: PAD (Au)

A. Free Carbohydrates Extract
B. Total Carbohydrates Extract
C. Mix of Standards

Peaks:
1. Mannitol 15 mg/L
2. Fucose 15
3. Rhamnose 35
4. Arabinose 40
5. Galactose 50
6. Glucose 55
7. Xylose 55
8. Mannose 45
9. Fructose 90
10. Ribose 90
### Precision: Mixed Carbohydrate Standard by AOAC Method 995.13

- Recommendation #2a as applied to instant coffee: 10 mM Base for 6 min
- Do not include *sucrose* in mix of standards

<table>
<thead>
<tr>
<th>Carbohydrate</th>
<th>Concn for Precision Injection (µg/mL)</th>
<th>Retention Time Precision (RSD)</th>
<th>Peak Area Precision (RSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>15</td>
<td>0.09</td>
<td>2.8</td>
</tr>
<tr>
<td>Fucose</td>
<td>15</td>
<td>0.46</td>
<td>2.6</td>
</tr>
<tr>
<td>Rhamnose</td>
<td>35</td>
<td>0.81</td>
<td>4.1</td>
</tr>
<tr>
<td>Arabinose</td>
<td>40</td>
<td>0.41</td>
<td>3.2</td>
</tr>
<tr>
<td>Galactose</td>
<td>50</td>
<td>0.27</td>
<td>3.2</td>
</tr>
<tr>
<td>Glucose</td>
<td>55</td>
<td>0.35</td>
<td>3.0</td>
</tr>
<tr>
<td>Xylose</td>
<td>55</td>
<td>0.33</td>
<td>5.0</td>
</tr>
<tr>
<td>Mannose</td>
<td>45</td>
<td>0.50</td>
<td>4.2</td>
</tr>
<tr>
<td>Fructose</td>
<td>90</td>
<td>0.42</td>
<td>3.0</td>
</tr>
<tr>
<td>Ribose</td>
<td>90</td>
<td>0.37</td>
<td>3.4</td>
</tr>
</tbody>
</table>

*n* = Six Injections
Recommendation #2b: for Green Coffee

- 10 mM Base for 6 min
- Do not include xylose and mannose in mix of standard for green coffee samples

Columns: Dionex CarboPac PA1
Eluent: 10 mM NaOH 0–6 min, DI water 6–50 min, 300 mM NaOH from 50 to 65 min, DI water from 65 to 80 min
Flow Rate: 1.0 mL/min
Temp: 25°C
Inj. Volume: 10 µL
Detection: PAD (Au)

A. Standards
B. Green Coffee Extract

Peaks:
1. Mannitol
2. Fucose
3. Rhamnose
4. Arabinose
5. Galactose
6. Glucose
7. Sucrose
8. Fructose
9. Ribose
Analyte Recovery: Total Carbohydrates—Instant Coffee

Carbohydrate Recoveries in Extract of Total Carbohydrates from Instant Coffee (n = Three Days) Using Modified\textsuperscript{a,b} AOAC Method 995.13

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/L)</th>
<th>Amount Detected (mg/L)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>97.3</td>
<td>105.0</td>
<td>107.5</td>
<td>9.3</td>
</tr>
<tr>
<td>Fucose</td>
<td>99.5</td>
<td>82.0</td>
<td>82.1</td>
<td>9.1</td>
</tr>
<tr>
<td>Rhamnose</td>
<td>106.0</td>
<td>101.0</td>
<td>71.1</td>
<td>14.0</td>
</tr>
<tr>
<td>Arabinose</td>
<td>91.5</td>
<td>186.0</td>
<td>88.8</td>
<td>15.0</td>
</tr>
<tr>
<td>Galactose</td>
<td>102.0</td>
<td>817.0</td>
<td>114.4</td>
<td>15.4</td>
</tr>
<tr>
<td>Glucose</td>
<td>92.8</td>
<td>113.0</td>
<td>84.6</td>
<td>9.9</td>
</tr>
<tr>
<td>Xylose</td>
<td>129.0</td>
<td>106.0</td>
<td>76.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Mannose</td>
<td>200.0</td>
<td>819.0</td>
<td>59.8</td>
<td>18.0</td>
</tr>
<tr>
<td>Fructose</td>
<td>103.0</td>
<td>89.7</td>
<td>87.1</td>
<td>12.4</td>
</tr>
<tr>
<td>Ribose</td>
<td>98.4</td>
<td>79.1</td>
<td>80.3</td>
<td>5.8</td>
</tr>
</tbody>
</table>

\textsuperscript{a} 10 mM base in the eluent in the first 6 min, followed by water; all other chromatography conditions the same as AOAC Method 995.13

\textsuperscript{b} Exclusion of sucrose from mix of standards
### Analyte Recovery: Free Carbohydrates—Instant Coffee

Carbohydrate Recoveries in Extract of Free Carbohydrates from Instant Coffee (n = Three Days) Using Modified\textsuperscript{a,b} AOAC Method 995.13

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/L)</th>
<th>Amount Detected (mg/L)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>39.5</td>
<td>47.7</td>
<td>116.1</td>
<td>18.1</td>
</tr>
<tr>
<td>Fucose</td>
<td>41.4</td>
<td>29.3</td>
<td>71.3</td>
<td>11.1</td>
</tr>
<tr>
<td>Rhamnose</td>
<td>45.1</td>
<td>40.5</td>
<td>89.5</td>
<td>6.8</td>
</tr>
<tr>
<td>Arabinose</td>
<td>36.6</td>
<td>61.0</td>
<td>77.9</td>
<td>20.6</td>
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<tr>
<td>Galactose</td>
<td>45.2</td>
<td>56.3</td>
<td>83.5</td>
<td>15.5</td>
</tr>
<tr>
<td>Glucose</td>
<td>42.2</td>
<td>43.5</td>
<td>92.4</td>
<td>9.6</td>
</tr>
<tr>
<td>Xylose</td>
<td>41.2</td>
<td>43.0</td>
<td>104.4</td>
<td>7.9</td>
</tr>
<tr>
<td>Mannose</td>
<td>41.2</td>
<td>58.7</td>
<td>83.3</td>
<td>19.2</td>
</tr>
<tr>
<td>Fructose</td>
<td>39.2</td>
<td>44.2</td>
<td>94.8</td>
<td>11.0</td>
</tr>
<tr>
<td>Ribose</td>
<td>49.9</td>
<td>43.2</td>
<td>85.1</td>
<td>17.3</td>
</tr>
</tbody>
</table>

\textsuperscript{a} 10 mM base in the eluent in the first 6 min, followed by water; all other chromatography conditions same as AOAC Method 995.13
\textsuperscript{b} Exclusion of sucrose from mix of standards
Analyte Recovery: Free Carbohydrates—Green Coffee

Carbohydrate Recoveries in Extract of Free Carbohydrates from Green Coffee (n = Three Days) Using Modified\textsuperscript{a,b} AOAC Method 995.13

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/L)</th>
<th>Amount Detected (mg/L)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>42.9</td>
<td>41.3</td>
<td>76.6</td>
<td>6.2</td>
</tr>
<tr>
<td>Fucose</td>
<td>95.2</td>
<td>90.7</td>
<td>95.4</td>
<td>12.8</td>
</tr>
<tr>
<td>Rhamnose</td>
<td>111.0</td>
<td>83.5</td>
<td>75.6</td>
<td>8.6</td>
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<tr>
<td>Arabinose</td>
<td>97.7</td>
<td>81.1</td>
<td>83.0</td>
<td>2.5</td>
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<tr>
<td>Galactose</td>
<td>104.0</td>
<td>97.8</td>
<td>92.2</td>
<td>7.6</td>
</tr>
<tr>
<td>Glucose</td>
<td>101.0</td>
<td>129.0</td>
<td>88.7</td>
<td>23.1</td>
</tr>
<tr>
<td>Sucrose</td>
<td>88.4</td>
<td>233.0</td>
<td>69.5</td>
<td>32.1</td>
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<tr>
<td>Fructose</td>
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<td>140.0</td>
<td>73.3</td>
<td>14.9</td>
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<tr>
<td>Ribose</td>
<td>109.0</td>
<td>90.7</td>
<td>83.3</td>
<td>5.6</td>
</tr>
</tbody>
</table>

\textsuperscript{a} 10 mM base in the eluent in the first 6 min, followed by water; all other chromatography conditions same as AOAC Method 995.13

\textsuperscript{b} Exclusion of xylose and mannose from mix of standards
Faster Method
Column for Rapid Separation of Plant Monosaccharides

Dionex CarboPac SA10 Column
Chromatographic Conditions for Fast Method

Column: Dionex CarboPac SA10, Guard (4 × 50 mm)
        Dionex CarboPac SA10, Analytical (4 × 250 mm)

Eluent: 1 mM KOH

Eluent Source: Thermo Scientific™ Dionex™ EGC II KOH

Flow Rate: 1.5 mL/min

Inj. Volume: 0.4 µL (Internal Loop)

Temperature: 45 ºC

Detection: PAD (Au)
Mixed Carbohydrate Standard Separated by the Fast Method

- **Column:** Dionex CarboPac SA10, Guard (4 × 50 mm)
- **Eluent:** 1 mM KOH
- **Eluent Source:** Dionex EGC II KOH
- **Flow Rate:** 1.5 mL/min
- **Inj. Volume:** 0.4 µL
- **Temperature:** 45 ºC
- **Detection:** PAD (Au)

**Peaks**

1. Mannitol 14 mg/mL
2. Fucose 14
3. Sucrose 45
4. Arabinose 38
5. Rhamnose/Galactose —
6. Glucose 50
7. Xylose 47
8. Mannose 37
9. Fructose/Ribose —
## Calibration and Precisions Using the Fast Method

### Linear Range and Precisions for Coffee Sugars

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Range (mg/mL)</th>
<th>Coeff of Deter.</th>
<th>Conc for Precision (mg/L)</th>
<th>Retention Time (min)</th>
<th>Retention Time Precision (RSD)</th>
<th>Peak Area (nC*min)</th>
<th>Peak Area Precision (RSD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mannitol</td>
<td>0.005–0.2</td>
<td>0.99917</td>
<td>15</td>
<td>2.06</td>
<td>0.21</td>
<td>0.16</td>
<td>1.35</td>
</tr>
<tr>
<td>Fucose</td>
<td>0.006–0.2</td>
<td>0.99980</td>
<td>15</td>
<td>2.89</td>
<td>0.15</td>
<td>0.13</td>
<td>3.25</td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.01–0.8</td>
<td>0.99587</td>
<td>45</td>
<td>3.61</td>
<td>0.19</td>
<td>0.29</td>
<td>3.28</td>
</tr>
<tr>
<td>Arabinose</td>
<td>0.018–0.3</td>
<td>0.99973</td>
<td>40</td>
<td>3.99</td>
<td>0.13</td>
<td>0.33</td>
<td>4.24</td>
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<td>Glucose</td>
<td>0.013–0.9</td>
<td>0.99631</td>
<td>55</td>
<td>4.74</td>
<td>0.20</td>
<td>0.75</td>
<td>3.64</td>
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<td>Xylose</td>
<td>0.01–0.74</td>
<td>0.99668</td>
<td>55</td>
<td>5.28</td>
<td>0.18</td>
<td>0.71</td>
<td>4.64</td>
</tr>
<tr>
<td>Mannose</td>
<td>0.006–0.7</td>
<td>0.99417</td>
<td>45</td>
<td>5.58</td>
<td>0.15</td>
<td>0.86</td>
<td>3.85</td>
</tr>
</tbody>
</table>
# Green and Instant Free and Total Carbohydrates

## Coffee Extracts Fast Method

<table>
<thead>
<tr>
<th>Peaks</th>
<th>Std (A)</th>
<th>Green (B)</th>
<th>Instant Total (C)</th>
<th>Instant Free (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Mannitol</td>
<td>—</td>
<td>0.054</td>
<td>0.006</td>
<td>0.017</td>
</tr>
<tr>
<td>2. Fucose</td>
<td>0.40</td>
<td>—</td>
<td>—</td>
<td>0.001</td>
</tr>
<tr>
<td>3. Sucrose</td>
<td>0.46</td>
<td>0.315</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4. Arabinose</td>
<td>0.42</td>
<td>—</td>
<td>0.126</td>
<td>0.041</td>
</tr>
<tr>
<td>5. Rhamnose/Galactose</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>6. Glucose</td>
<td>0.47</td>
<td>0.059</td>
<td>0.032</td>
<td>—</td>
</tr>
<tr>
<td>7. Xylose</td>
<td>0.45</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>8. Mannose</td>
<td>0.41</td>
<td>0.001</td>
<td>0.603</td>
<td>0.028</td>
</tr>
<tr>
<td>9. Fructose/Ribose</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

![Graph showing peaks and corresponding data for different carbohydrates](image-url)

**Graph Key:**
- A: Standard (Std)
- B: Green
- C: Instant Total
- D: Instant Free

**Time Scale:**
- Minutes from 0 to 10
- Signal offset: 10%

**Units:**
- nC (nanocoulombs)
## Accuracy of the Fast Method for Green Coffee Extract

### Sugar Recoveries in an Extract of Free Sugars from Green Coffee (n = Three Days)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/mL)</th>
<th>Amount Detected (mg/mL)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fucose</td>
<td>0.10</td>
<td>0.08</td>
<td>86.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.16</td>
<td>0.39</td>
<td>73.9</td>
<td>7.3</td>
</tr>
<tr>
<td>Arabinose</td>
<td>0.09</td>
<td>0.09</td>
<td>97.4</td>
<td>16.9</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.11</td>
<td>0.14</td>
<td>83.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Xylose</td>
<td>0.11</td>
<td>0.08</td>
<td>75.3</td>
<td>14.4</td>
</tr>
<tr>
<td>Mannose</td>
<td>0.10</td>
<td>0.08</td>
<td>78.0</td>
<td>17.8</td>
</tr>
</tbody>
</table>
Sugar Recoveries in an Extract of **Total Sugars** from Instant Coffee (n = Three Days)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/mL)</th>
<th>Amount Detected (mg/mL)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fucose</td>
<td>0.10</td>
<td>0.11</td>
<td>105.9</td>
<td>12.6</td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.09</td>
<td>0.10</td>
<td>107.7</td>
<td>6.9</td>
</tr>
<tr>
<td>Arabinose</td>
<td>0.09</td>
<td>0.11</td>
<td>127.7</td>
<td>5.1</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.09</td>
<td>0.37</td>
<td>101.3</td>
<td>7.1</td>
</tr>
<tr>
<td>Xylose</td>
<td>0.10</td>
<td>0.16</td>
<td>114.5</td>
<td>7.8</td>
</tr>
<tr>
<td>Mannose</td>
<td>0.09</td>
<td>0.11</td>
<td>120.5</td>
<td>11.5</td>
</tr>
</tbody>
</table>

Sugar Recoveries in an Extract of **Free Sugars** from Instant Coffee (n = Three Days)

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Amount Added (mg/mL)</th>
<th>Amount Detected (mg/mL)</th>
<th>Recovery (%)</th>
<th>RSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fucose</td>
<td>0.04</td>
<td>0.04</td>
<td>85.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Sucrose</td>
<td>0.05</td>
<td>0.04</td>
<td>81.4</td>
<td>13.1</td>
</tr>
<tr>
<td>Arabinose</td>
<td>0.03</td>
<td>0.03</td>
<td>102.4</td>
<td>14.2</td>
</tr>
<tr>
<td>Glucose</td>
<td>0.05</td>
<td>0.08</td>
<td>98.0</td>
<td>9.9</td>
</tr>
<tr>
<td>Xylose</td>
<td>0.04</td>
<td>0.03</td>
<td>78.9</td>
<td>24.9</td>
</tr>
<tr>
<td>Mannose</td>
<td>0.05</td>
<td>0.04</td>
<td>80.0</td>
<td>16.0</td>
</tr>
</tbody>
</table>
• Dionex CarboPac PA1 (AOAC Method) has two reported issues. Our recommendations to resolve these issues:
  • Use low temp to resolve all 11 carbohydrates.
  • Use initial base (step change) to resolve rhamnose-arabinose.
  • For instant coffee analysis, remove sucrose from the standard mix.

• Dionex CarboPac SA10 reduces analysis time eightfold.
  • However, two pairs (rhamnose-galactose and ribose-fructose) are not resolved.
Thank you!