Table of Contents

Chromatography for Foods and Beverages

Carbohydrates Analysis Applications Notebook

Novel, Selective, Sensitive Analytical Methods

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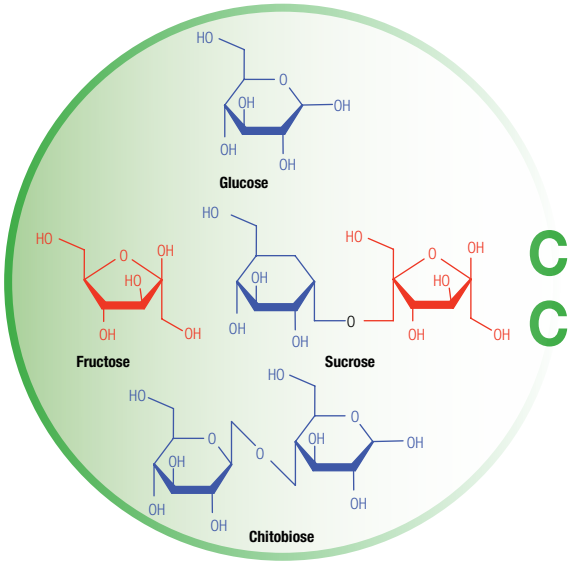
Table of Contents

Chapter 1: Carbohydrates



Chromatography of Carbohydrates

Carbohydrates are important food components affecting taste and nutrition. The determination of the types and concentrations of carbohydrates in foods is integral for energy evaluation, nutritional labeling, quality control, and for identifying possible adulteration. This section describes a variety of approaches for the measurement of simple carbohydrates and dietary fiber.

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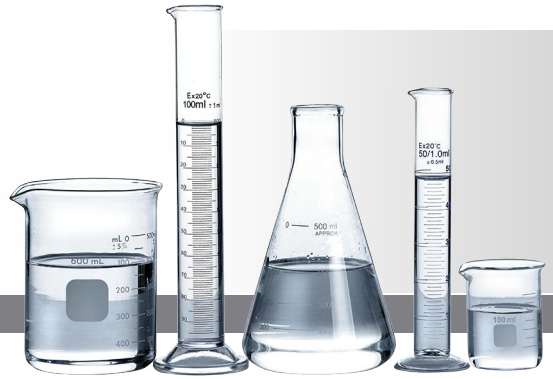
Table of Contents



Food Compendium: Analytical Technologies

High-Performance Liquid Chromatography

Thermo Scientific™ Dionex™ UltiMate™ 3000 UHPLC+ systems offer excellent chromatographic performance, operational simplicity and unrivaled flexibility. Choose from a wide range of standard and unique specialty detectors to extend your laboratory's analytical capabilities.

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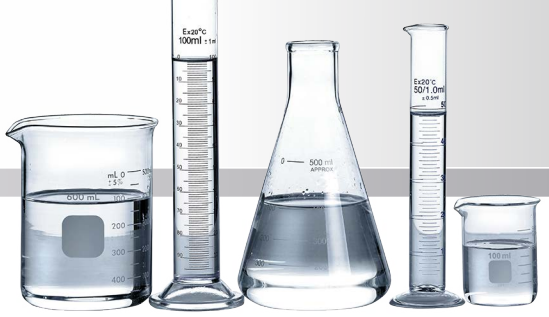

UltiMate 3000 UHPLC+ Systems

Best-in-class HPLC systems for all your chromatography needs

UltiMate 3000 UHPLC+ Systems provide excellent chromatographic performance while maintaining easy, reliable operation. The basic and standard analytical systems offer ultra HPLC (UHPLC) compatibility across all modules, ensuring maximum performance for all users and all laboratories.

Covering flow rates from 20 nL/min to 10 mL/min with an industry-leading range of pumping, sampling, and detection modules, UltiMate 3000 UHPLC+ Systems provide solutions from nano to semipreparative, from conventional LC to UHPLC.

Superior chromatographic performance

- UHPLC design philosophy throughout nano, standard analytical, and rapid separation liquid chromotography (RSLC)
- 620 bar (9,000 psi) and 100 Hz data rate set a new benchmark for basic and standard analytical systems
- RSLC systems go up to 1000 bar and data rates up to 200 Hz
- ×2 Dual System for increased productivity solutions in routine analysis
- Fully UHPLC compatible advanced chromatographic techniques
- Thermo Scientific™ Dionex™ Viper™ and nanoViper™ fingertight fittings—the first truly universal, fingertight fitting system even at UHPLC pressures

Table of Contents

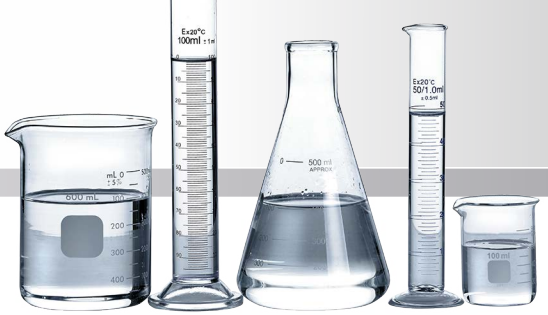

Table of Contents

UltiMate 3000 UHPLC+ Systems

We are uniquely focused on making UHPLC technology available to all users, all laboratories, and for all analytes.

Rapid Separation LC Systems
The extended flowpressure footprint of the RSLC system provides the performance for ultrafast high-resolution and conventional LC applications.

Standard LC Systems
Choose from a wide variety of standard LC systems for demanding LC applications at nano, capillary, micro, analytical, and semipreparative flow rates.

RSLCnano Systems
The Rapid Separation nano LC System (RSLCnano) provides the power for high resolution and fast chromatography in nano, capillary, and micro LC.

Basic LC Systems
UltiMate 3000 Basic LC Systems are UHPLC compatible and provide reliable, high performance solutions to fit your bench space and your budget.

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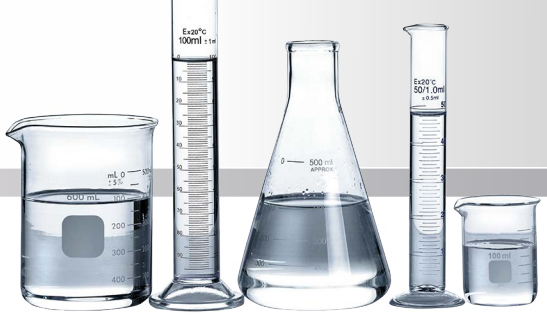


Standard HPLC Detectors

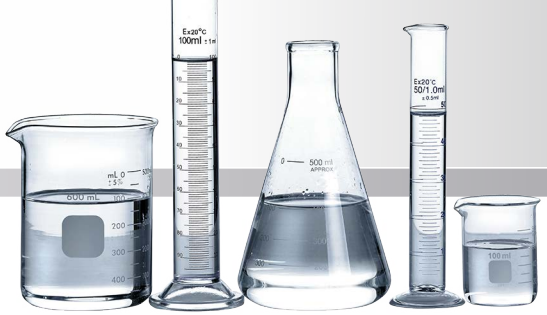
UltiMate 3000 Variable Wavelength Detectors

The Thermo Scientific Dionex UltiMate 3000 VWD-3000 is a variable wavelength detector (VWD) series for industry leading UV-Vis detection. The forward optics design and wide range of available flow cells ensure optimal performance over a flow rate range of five orders of magnitude. Automated qualification, performance optimization, and instrument wellness monitoring deliver maximum uptime, simplify work-flow, and give you full confidence in your analytical results. The detector is available in a standard 100 Hz (VWD-3100) and a 200 Hz Rapid Separation version (VWD-3400RS) for the most challenging UHPLC applications.

High-Performance UV-Vis Detection

- The VWD-3400RS variant provides data collection rates of up to 200 Hz for optimal support of today's and tomorrow's UHPLC separations
- The VWD-3100 standard detector operates at up to 100 Hz data rate for optimum support of 62 MPa (9000 psi) UltiMate 3000 Standard systems
- Superior detection of trace analytes with low noise (< –2.0 µAU) and drift (< 100 µAU/h)
- The detector's large linearity range of up to 2.5 AU is ideal for applications with widely varying analyte concentrations
- Up to four absorption channels (VWD-3400RS) and spectral scans support effective method development
- Active temperature control of optics and electronics for data acquisition independent of ambient conditions
- Front panel access for quick and easy lamps and flow cells changes
- Automated qualification monitoring for full regulatory compliance
- Large front panel display for monitoring the detector status even from a distance
- Maximize uptime using predictive performance–based on monitoring the life cycle of detector lamps
- The detector can be upgraded with the Thermo Scientific Dionex pH/Conductivity Monitor (PCM-3000) for accurate and precise pH- and conductivity monitoring
- Unique 45 nL ultra-low dispersion UV monitor for dispersion-free UV detection in LC/MS

UltiMate 3000 VWD-3400 Variable Wavelength Detector.



Standard HPLC Detectors

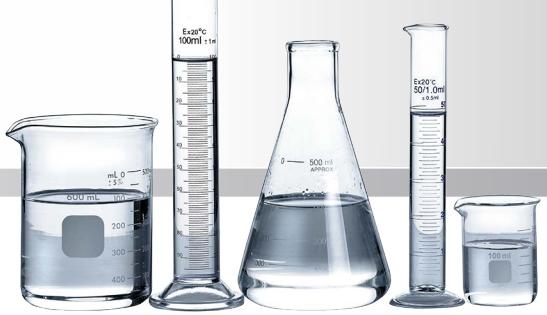
UltiMate 3000 Diode Array and Multiple-Wavelength Detectors

The Thermo Scientific Dionex UltiMate DAD 3000 detector is a high-resolution, 1024-element diode array detector (DAD) available in Rapid Separation (200 Hz) and Standard (100 Hz) versions. It operates with the Thermo Scientific™ Dionex™ Chromeleon™ Chromatography Data System (CDS) software to provide a variety of spectra views, including 3-D plotting and automated chromatogram handling. The high resolution and low-noise performance of the DAD-3000 family makes it ideal for the most sensitive and accurate library searches and peak purity analyses.

The detector is also available as a multiple wavelength detector (MWD) in Standard (100 Hz) and Rapid Separation (200 Hz) versions.

- Data collection at up to 200 Hz using a maximum of eight single-wavelength data channels and one 3-D field (3-D only with DAD-3000 (RS)) for best support of ultrafast separations
- Standard versions operate at up to 100 Hz data collection rate for optimum support of 62 MPa (9000 psi) UltiMate 3000 Standard systems
- Accurate compound confirmation with a 1024-element, high resolution photodiode array
- Flexibility in both UV and Vis applications with 190–800 nm wavelength range
- Low-noise over the full spectral range using deuterium and tungsten lamps
- Fast and accurate wavelength verification using a built-in holmium oxide filter
- The detector can be upgraded with the UltiMate PCM 3000 for accurate monitoring pH gradients
- Excellent reliability and reproducibility with low baseline drift (typically < 500 µAU/h)
- Simplified routine maintenance with front access to pre-aligned cells and lamps
- ID chips on flow cells and lamps for identification and life-span monitoring
- Chromeleon CDS software for full control and flexible data handling
- Front-panel display for easy monitoring of detector status to maximize uptime
- Flow cells for semi-micro, semi-analytical, analytical, and semi-preparative applications
- Flow cells available in stainless steel and biocompatible versions

UltiMate 3000 DAD-3000 Diode Array Detector



Standard HPLC Detectors

RefractoMax 521 Refractive Index Detector

The Thermo Scientific RefractoMax 521 Refractive Index Detector from ERC Inc. This detector, in combination with the UltiMate 3000 system, is the right choice for the isocratic analysis of sugars, polymers, and fatty acids. It features fast baseline stabilization and excellent reproducibility, combined with high sensitivity. The RefractoMax 521 is fully controlled by the Chromeleon CDS, and can also operate in stand-alone mode.

- The detector is highly sensitive and applicable universally. It provides very stable baselines with a drift of 0.2 µRIU/h and a noise specification of 2.5 nRIU or less
- The optical bench, thermostatically regulated from 30 °C to 55 °C, and the superior signal-to-noise ratio ensure highly precise measurement results
- The extended flow rate range from 1 mL/min up to 10 mL/min and the operating range of 1.00 to 1.75 RIU enable the use of this detector for a wide range of applications
- Applications include the analysis of all compounds with low UV-Vis activity, such as alcohols, mono- and polysaccharides, esters, fatty acids, or polymers
- An Auto Set-up function automates purging, equilibration, autozero, and the control baseline stability and noise
- Operation with Chromeleon CDS makes the detector easy to use and ensures maximum productivity in instrument control, data processing, and reporting of results

RefractoMax 521 Refractive Index Detector

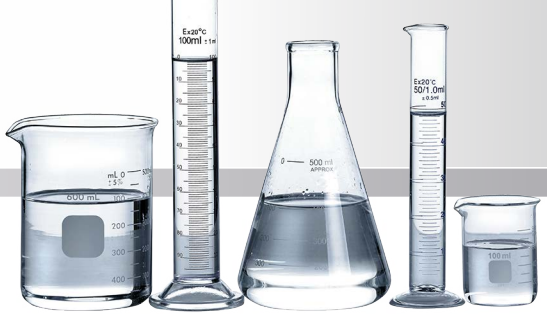


Table of Contents

Specialty HPLC Detectors

Corona Veo Charged Aerosol Detector

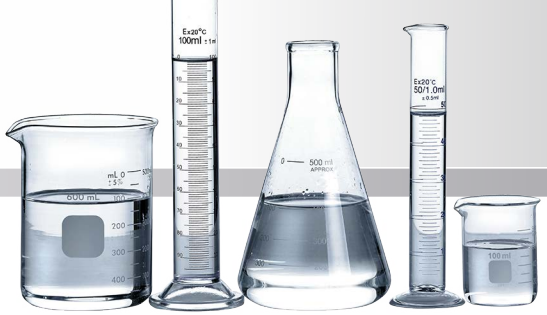
Charged Aerosol Detection provides near universal detection independent of chemical structure for non- or semi-volatile analytes with HPLC and UHPLC. A Thermo Scientific™ Dionex™ Corona™ Veo™ Charged Aerosol detector is ideally suited as a primary detector for any laboratory, while providing complementary data to UV or MS methods. No other LC detector available today can match the performance of a Corona Veo detector.

- High sensitivity – single-digit nanogram on column
- Consistent response – independent of chemical structure
- Wide dynamic range – to four orders of magnitude or greater
- Simple to use – easy to integrate with any HPLC/UHPLC system

The Corona Veo detector gives the simplicity, reproducibility and performance required for a full range of applications from basic research to manufacturing QC/QA. With charged aerosol detection you get predictable responses to measure analytes in direct proportion to their relative amounts for quantitation without actual standards.

This detector offers the flexibility to use reversed-phase gradients, as well as normal phase and HILIC modes of separation on any LC system. And, in many cases eliminates the need for derivatization or sample pre-treatment to provide real dilute-and-shoot simplicity.

Corona Veo Charged Aerosol Detector



Specialty HPLC Detectors

Table of Contents

Ultimate 3000 Electrochemical Detector

Electrochemical detection delivers high sensitivity for neurotransmitter analysis, simplicity and robustness for pharmaceutical or clinical diagnostics, and the selectivity for the characterization of complex samples such as natural products, biological tissues and fluids. For today's researcher, there is a continuing need for detecting vanishingly small quantities of analyte and often in complex samples. Because electrochemical detection measures only compounds that can undergo oxidation or reduction it is both highly sensitive and very selective.

The Thermo Scientific Dionex UltiMate 3000 Electrochemical Detector, designed by the pioneers of coulometric electrochemical detection, delivers state-of-the-art sensor technologies complete with an entire range of high performance and ultra-high performance LC systems optimized for electrochemical detection. The UltiMate 3000 ECD-3000RS takes electrochemical detection to the next level with UHPLC compatibility, total system integration, and selection of detection mode, all with unprecedented operational simplicity.

Features include:

- Detection Modes – choose from DC and PAD for optimum analyte response
- Choice of sensors – both coulometric and amperometric sensors to meet the demands of any application
- UHPLC compatibility – ultralow peak dispersion and high data acquisition rates for conventional or fast, high resolution chromatography
- Modularity – easily expandable to multiple independent sensors for unrivaled flexibility
- Autoranging – simultaneously measure both low and high levels of analytes without losing data
- SmartChip™ technology – easy operation with automatic sensor recognition, event logging and electrode protection

UltiMate 3000 Electrochemical Detector

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Learn more at www.thermoscientific.com/ECDetection

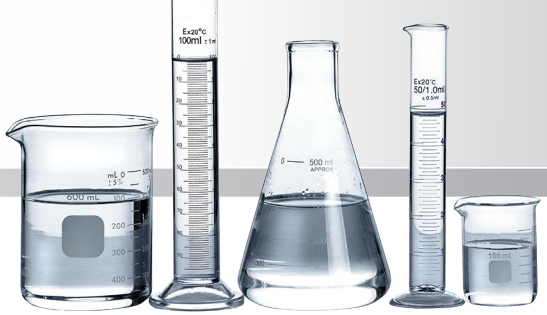

Table of Contents

Specialty HPLC Detectors

CoulArray Multi-electrode Array Detector

The Thermo Scientific™ Dionex™ CoulArray™ Multi-electrode Array detector is the only practical multi-channel electrochemical detection system that allows you to measure multiple analytes simultaneously, including those that are chromatographically unresolved. The CoulArray detector delivers the widest dynamic range of any available electrochemical detector with unmatched selectivity for detection of trace components in complex matrixes, even when used with aggressive gradients.

- Measures analytes from femtomole to micromole levels
- Greatly simplify sample preparation and eliminate interferences
- Simultaneously analyze multiple analytes in very complex samples
- Easily produce qualitative information for compound identification

Multiple system configurations offer 4, 8, 12, or 16 channels that can be upgraded anytime. The unique data acquisition and processing software uses automatic signal ranging and a unique patented baseline correction algorithms to provide identification and quantitation of single or multiple analytes and powerful 3D data for quick sample fingerprint confirmation with integration to pattern recognition platforms.

With the power of coulometric array technology, the CoulArray detector can give you the qualitative data of a optical PDA with 1,000 fold greater sensitivity to profile the characteristic qualities of products, determine integrity, identify adulteration and even evaluate competitors' products.

CoulArray Multi-electrode Array Detector

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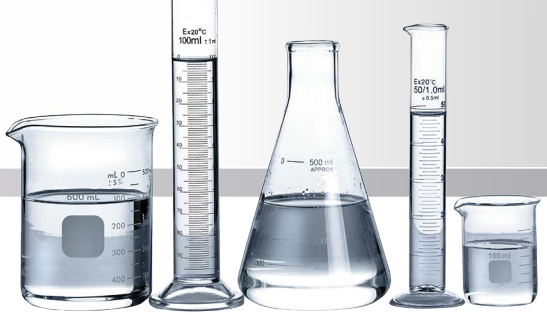


Specialty HPLC Detectors

Table of Contents

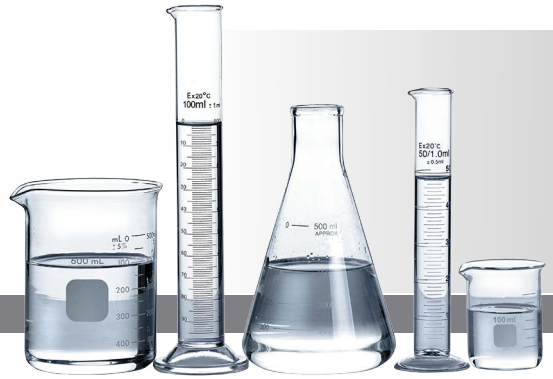
Ultimate 3000 Fluorescence Detector

The Thermo Scientific Dionex UltiMate 3000 FLD-3000 is a high-sensitivity fluorescence detector series for UltiMate 3000 HPLC systems. It is available in Rapid Separation (RS) and Standard (SD) versions. The optics of the FLD-3000 series provide maximum stray-light suppression for best detection sensitivity. Operated with the Chromeleon CDS software, the detector provides automated qualification, various tools for method development, and instrument wellness monitoring for ease of use, maximum uptime, and the highest degree of regulatory compliance.

- Data collection at up to 200 Hz for optimal support of even the fastest UHPLC separations (FLD-3400RS)
- Standard detectors operate at up to 100 Hz data rate for optimum support of 62 MPa (9,000 psi) UltiMate 3000 standard systems
- Lowest limits of detection with a Raman signal-to-noise ratio (S/N): > 550 ASTM (> 2100 using dark signal as noise reference)
- Unsurpassed reproducibility with active flow cell temperature control for stable fluorophore activity independent of changes in ambient temperature
- Long-life xenon flash lamp for highest sensitivity and long-term operation without the need for frequent lamp changing
- Optional second photomultiplier (PMT) for unique Dual-PMT operation, offering an extended wavelength range up to 900 nm without sacrificing sensitivity in the standard wavelength range
- Two-dimensional (2D) or three dimensional (3D) excitation, emission, or synchro scans to provide the highest degree of flexibility for method development or routine sample characterization
- Innovative Variable Emission Filter for real-time compound-related sensitivity optimization (FLD-3400RS only)
- Large front-panel display for easy monitoring of the detector status
- Two flow-cell sizes for easy optimization to application requirements: the 8 µL flow cell is ideal for trace analysis, and the 2 µL flow cell offers best peak resolution with narrow-bore HPLC and UHPLC columns

Ultimate 3000 Fluorescence Detector

Table of Contents



Food Compendium: Analytical Technologies

Ion Chromatography

Thermo Scientific Dionex IC systems have led the analytical instrument industry for over 30 years with solutions that represent state-of-the art technological advancements and patented technologies.

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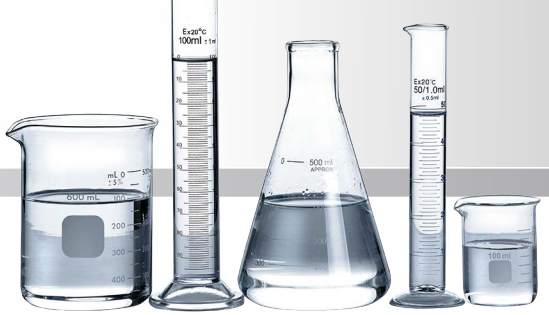


IC and RFIC Systems

Innovative Ion Chromatography Solutions

Our High-Pressure™ Ion Chromatography (HPIC™) systems include the Thermo Scientific Dionex ICS-5000+ HPIC system, which is optimized for flexibility, modularity, and ease-of-use, combining the highest chromatographic resolution with convenience. In addition, the Thermo Scientific Dionex ICS-4000 Capillary HPIC system is the world's first commercially available dedicated capillary high-pressure Reagent-Free™ (RFIC™) IC system. The Dionex ICS-4000 system is always ready for the next analysis, delivering high-pressure IC on demand.

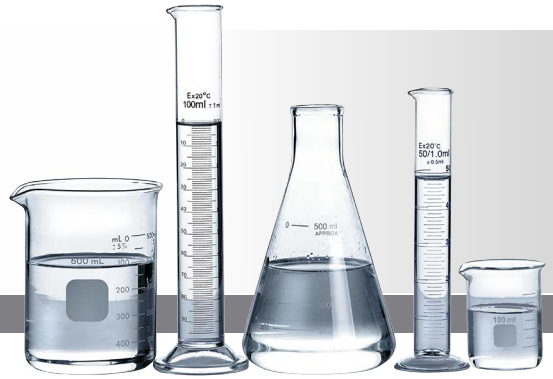
Reagent-Free IC systems eliminate daily tasks of eluent and regenerant preparation in turn saving time, preventing errors, and increasing convenience. RFIC-EG systems use electrolytic technologies to generate eluent on demand from deionized water, and to suppress the eluent back to pure water to deliver unmatched sensitivity. RFIC-ER systems are designed to use carbonate, carbonate/ bicarbonate, or MSA eluents for isocratic separations.

At the heart of our ion chromatography portfolio is a unique set of column chemistries that provide high selectivities and efficiencies with excellent peak shape and resolution. Thermo Scientific™ Dionex™ IonPac™ chromatography columns address a variety of chromatographic separation modes including ion exchange, ion exclusion, reversed-phase ion pairing, and ion suppression. Our column chemistries are designed to solve specific applications, and we offer a variety of selectivities and capacities for simple and complex samples. Additionally, our Dionex IonPac column line is available in standard bore, microbore and capillary formats for the ultimate application flexibility.

Thermo Scientific Dionex IC instrument family

Table of Contents

Table of Contents



Food Compendium: Analytical Technologies

Mass Spectrometry

Thermo Fisher Scientific provides advanced integrated IC/MS and LC/MS solutions with superior ease-of-use and modest price and space requirements. UltiMate 3000 System Wellness technology and automatic MS calibration allow continuous operation with minimal maintenance. The Dionex ion chromatography family automatically removes mobile phase ions for effort-free transition to MS detection.

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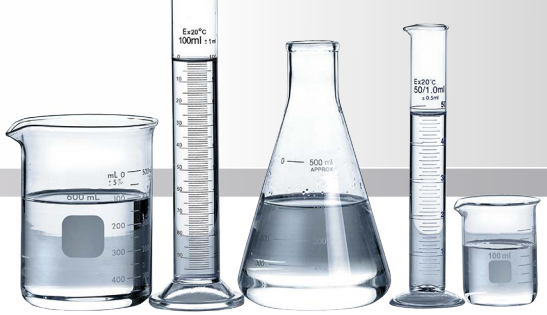

Mass Spectrometry Instruments

Single-Point Control and Automation

Thermo Fisher Scientific provides advanced integrated IC/MS and LC/MS solutions with superior ease-of-use and modest price and space requirements. UltiMate 3000 System Wellness technology and automatic MS calibration allow continuous operation with minimal maintenance. The Dionex ion chromatography family automatically remove mobile phase ions for effort-free transition to MS detection.

- Thermo Scientific™ MSQ Plus™ mass spectrometer, the smallest and most sensitive single quadrupole on the market for LC and IC
- Self-cleaning ion source for low maintenance operation
- Chromeleon CDS software for single-point method setup, instrument control, and data management compatible with existing IC and LC methods
- The complete system includes the MSQ Plus mass spectrometer, PC data system, electrospray ionization (ESI) and atmospheric pressure chemical ionization (APCI) probe inlets, and vaccum system

Now, you no longer need two software packages to operate your LC/MS system. Chromeleon CDS software provides single-software method setup and instrument control; powerful UV, conductivity, and MS data analysis; and fully integrated reporting.

MSQ Plus Mass Spectrometer

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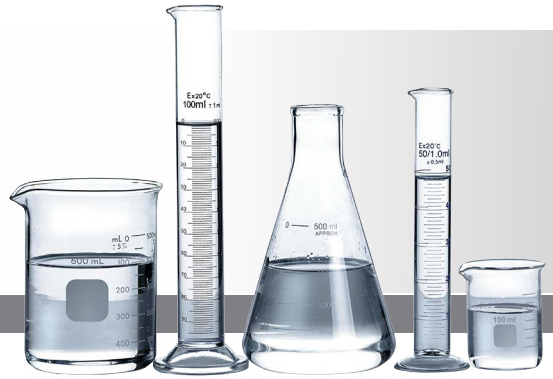
Table of Contents



Food Compendium: Analytical Technologies

Chromatography Data Systems

Tackle chromatography management challenges with the world's most complete chromatography software. Whether your needs are simple or complex or your scope is a single instrument, a global enterprise, or anything in between – the combination of Chromeleon CDS' scalable architecture and unparalleled ease-of use, makes your job easy and enjoyable with one Chromatography Data System for the entire lab.

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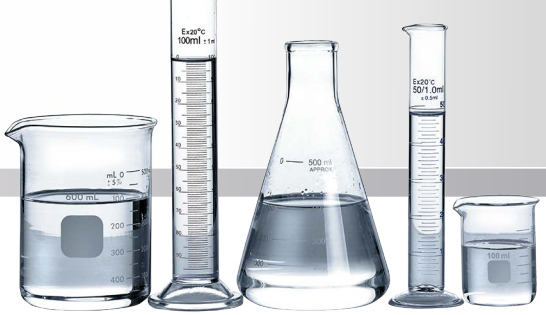

Chromeleon CDS Software

Table of Contents

The Fastest Way from Samples to Results

The 7.2 release of Chromeleon Chromatography Data System software is the first CDS that combines separation (GC/IC/LC) and Mass Spectrometry (MS) in an enterprise (client/server) environment. By extending Chromeleon 7.2 CDS beyond chromatography into MS, lab technicians can now streamline their chromatography and MS quantitation workflows with a single software package. MS support in Chromeleon 7.2 CDS is focused on routine and quantitative workflows, which provides access to rich quantitative data processing and automation capabilities — ultimately boosting your overall lab productivity and increasing the quality of your analytical results.

- Enjoy a modern, intuitive user interface designed around the principle of operational simplicity
- Streamline laboratory processes and eliminate errors with eWorkflows™, which enable anyone to perform a complete analysis perfectly with just a few clicks
- Access your instruments, data, and eWorkflows instantly in the Chromeleon Console
- Locate and collate results quickly and easily using powerful built-in database query features
- Interpret multiple chromatograms at a glance using MiniPlots
- Find everything you need to view, analyze, and report data in the Chromatography Studio
- Accelerate analyses and learn more from your data through dynamic, interactive displays
- Deliver customized reports using the built-in Excel compatible speadsheet

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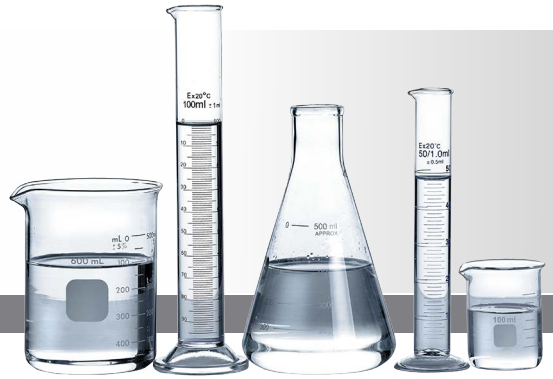
Table of Contents



Food Compendium: Analytical Technologies

Process Analytical Systems

Thermo Scientific Dionex process analytical systems provide timely results by moving chromatography-based measurements on-line.

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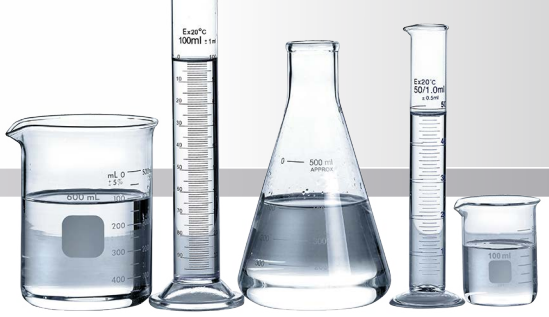


Process Analytical Systems and Software

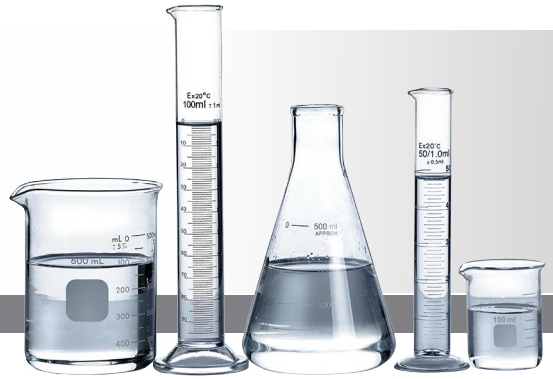
Improved Process Monitoring with On-line Chromatography IC and LC Systems

Information from the Thermo Scientific Dionex Integral process analyzer can help reduce process variability, improve efficiency, and reduce downtime. These systems provide comprehensive, precise, accurate information faster than is possible with laboratory-based results. From the lab to the factory floor, your plant's performance will benefit from the information provided by on-line LC.

- Characterize your samples completely with multicomponent analysis
- Reduce sample collection time and resources with automated multipoint sampling
- Improve your process control with more timely results
- See more analytes with unique detection capabilities
- The Thermo Scientific Integral Migration Path approach lets you choose the systems that best meets your needs

Integral process analyzer

Table of Contents



Food Compendium: Analytical Technologies

Automated Sample Preparation

Solvent extractions that normally require labor-intensive steps are automated or performed in minutes, with reduced solvent consumption and reduced sample handling using the Thermo Scientific™ Dionex™ ASE™ Accelerated Solvent Extractor system or Thermo Scientific™ Dionex™ AutoTrace™ 280 Solid-Phase Extraction instrument.

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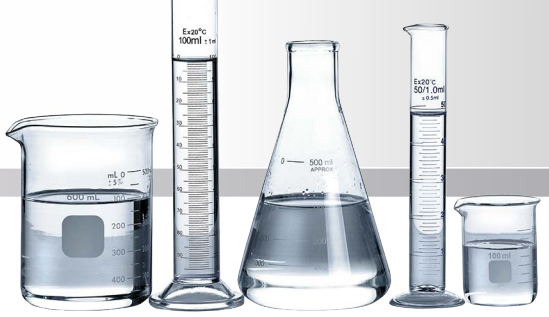

Accelerated Solvent Extractor System

Table of Contents

Complete Extractions in Less Time Using Less Solvent

Thermo Scientific Dionex ASE systems extract of solid and semisolid samples using common solvents at elevated temperature and pressure. The Dionex ASE 150 and 350 systems feature pH-hardened pathways with Dionium™ components to support extraction of acidic or alkaline matrices, and combine pretreatment, solvent extraction, and cleanup into one step. Dionium is zirconium that has undergone a proprietary hardening process that makes it inert to chemical attack by acids and bases at elevated temperatures.

Dionex ASE systems are dramatically faster than Soxhlet, sonication, and other extraction methods, and require significantly less solvent and labor. Accelerated solvent extraction methods are accepted and established in the environmental, pharmaceutical, foods, polymers and consumer product industries. Accelerated solvent extraction methods are accepted and used by government agencies worldwide.

Dionex ASE 150/350 and Dionex AutoTrace 280 SPE instruments

Analysis by HPLC-CAD

Table of Contents

Carbohydrates can be separated using hydrophilic interaction liquid chromatography (HILIC) and detected using charged aerosol detection.

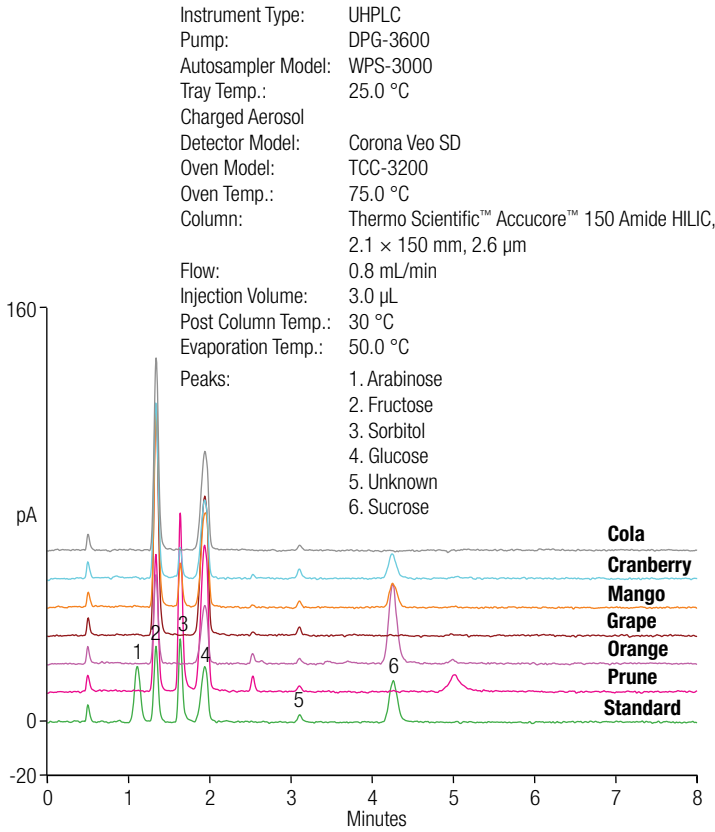

Figure 1-1. Analysis of various carbohydrates in beverages using HILIC-Charged Aerosol Detection.

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Analysis by HPLC-PAD

Carbohydrates can be separated by high performance liquid chromatography (HPLC) using an anion exchange column under basic conditions and measured using pulsed amperometric detection (PAD) on a gold working electrode. This approach is both sensitive and selective.

Column:	Anion Exchange, 4.6 × 250 mm, 7 µm
Flow:	Isocratic at 1.50 mL/min with constant He purge
Mobile Phase:	100 mM sodium hydroxide (NaOH), prepared from pellets, 99.99%, semiconductor grade
EC Detector:	Coulochem III, Thermo Scientific Dionex model 5040 cell with 25 µm Mylar gasket, Au Target
EC Parameters:	E1 +200 mV 500 ms AD 300 ms E2 -1000 mV 10 ms E3 +600 mV 1 ms E4 -100 mV 10 ms
Peaks:	1. Mannitol 2. Glucose 3. Fructose 4. Lactose

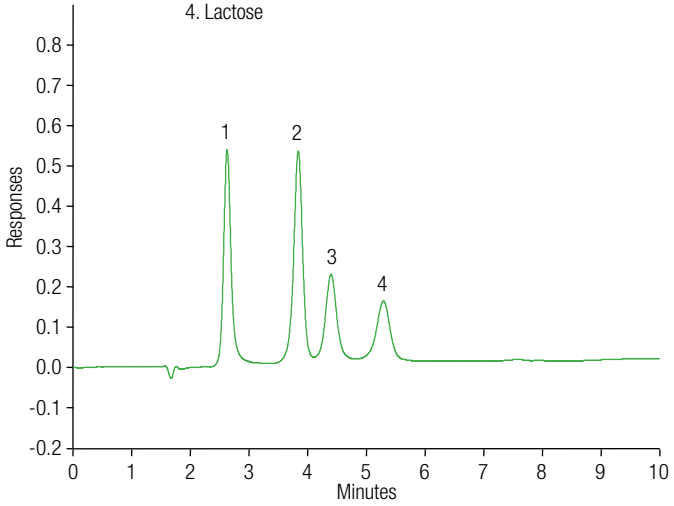

Figure 1-2. Analysis of simple carbohydrates by HPLC-PAD.

Pump:	LPG-3400 SD
Autosampler:	WPS-3000TSL Analytical Autosampler
Column:	Anion Exchange, 4.1 × 250 mm, 7 µm
Flow:	1.5 mL/min
Temperature:	30 °C
Injection Volume:	50 µL partial loop
Mobile Phase:	20 mM sodium hydroxide (NaOH) for 20 min, 6 min flush with 200 mM NaOH at end of run, 15 min equilibration before next injection.
EC detector:	ECD-3000RS, 6011RS cell with AU target, 25 µm Mylar Gasket
EC Parameters:	E1 +200 mV 500 ms AD 300 ms E2 -2000 mV 10 ms E3 +600 mV 10 ms E4 -100 mV 10 ms
Range:	500 nC
Peaks:	1. Galactose 2. Glucose 3. Lactose 4. Lactulose

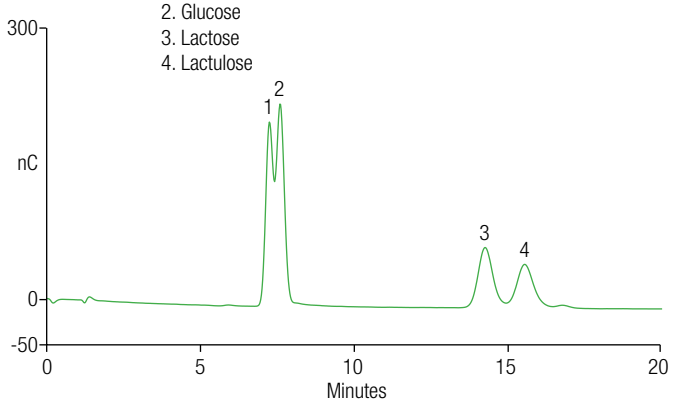

Figure 1-3. Analysis of lactose and lactulose in milk.

Analysis by HPLC-RI

Carbohydrates can be separated using hydrophilic interaction liquid chromatography (HILIC) and detected using refractive index (RI) detection.

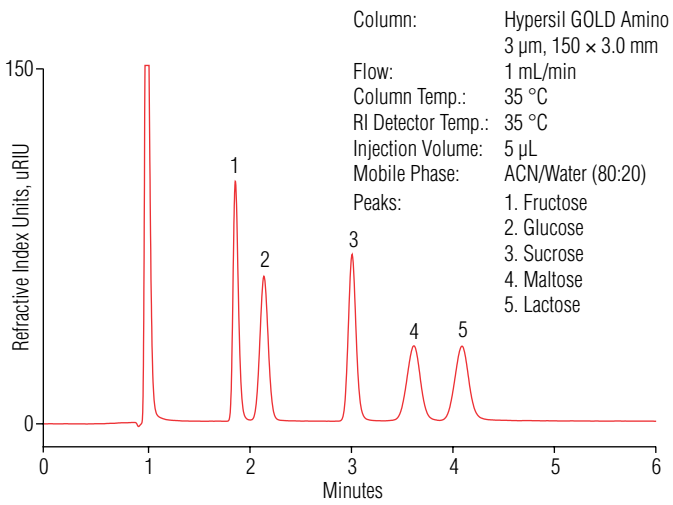

Figure 1-4. Separation of five sugars on a Thermo Scientific™ Hypersil GOLD™ Amino column.

Did You Know?

- Sugar possesses antibiotic properties and can be used to heal wounds.
- Sugar is used in leather tanning, metal plating baths, printers' inks and dyes, and even in textile sizing and finishing.

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Analysis by HPAE-PAD

Table of Contents

Carbohydrates can be separated using either standard column format (Technical Note 20) or a capillary format (Application Brief 127) using high performance anion exchange (HPAE) chromatography under basic conditions on an ion chromatographic system and measured using pulsed amperometric detection (PAD).

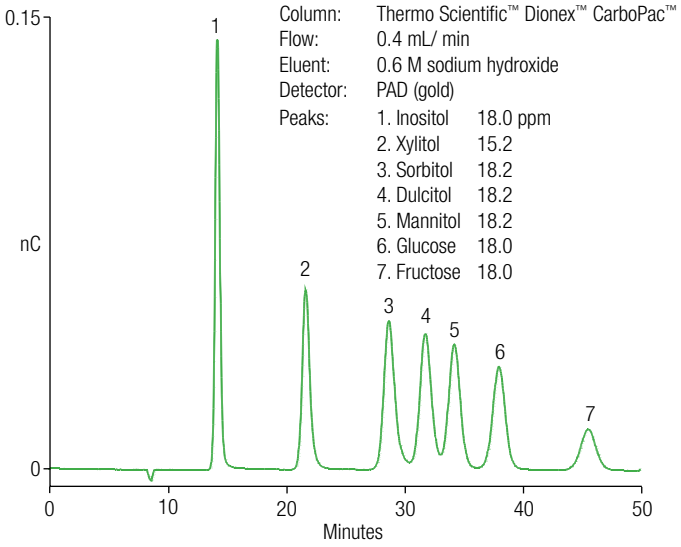

Figure 1-5. Isocratic separation of a group of alditols plus glucose and fructose on the Dionex CarboPac MA1 column.

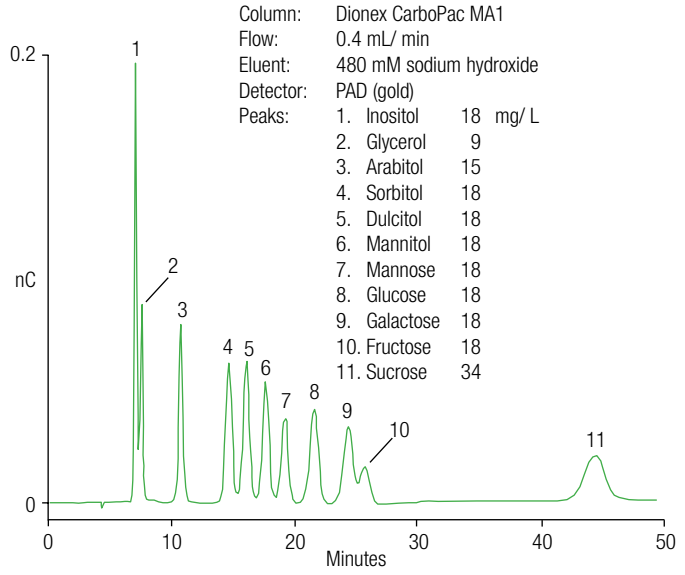

Figure 1-6. Separation of reducing and nonreducing carbohydrates. Food alditols and aldoses are separable under isocratic conditions on the Dionex CarboPac MA1.

Download Technical Note 20: Analysis of Carbohydrates by HPAE-PAD

Download Application Brief 127: Determination of Carbohydrates in Fruit Juice Using Capillary HPAE-PAD

Analysis by HPAE-MS

Carbohydrates can be separated at high pH values as anions on anion-exchange columns using sodium hydroxide and sodium acetate eluents.

High-value pH eluents are not directly compatible for introduction into an MS. Before MS detection, the eluent is first run through a high-capacity supressor (desalter), which lowers the pH to neutral levels.

MS detection is challenging because carbohydrates at neutral pH cannot be directly ionized by electrospray ionization. Therefore, 0.5 mmol/L LiCl is added to the desalted eluent postsuppressor to create an ionic species suitable for MS detection.

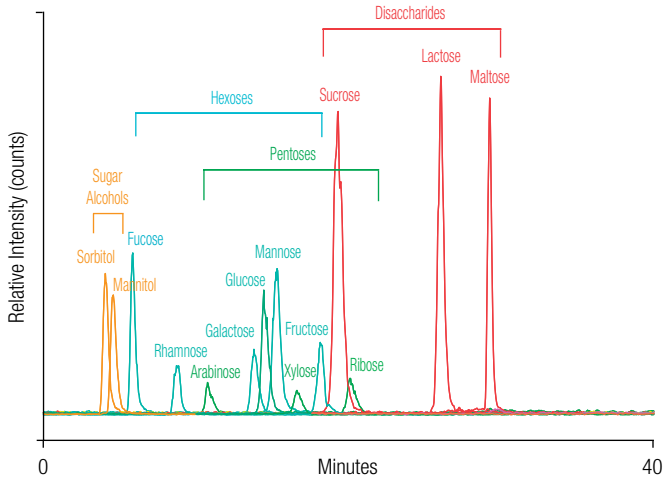

Figure 1-7. Electrospray ionization of sugar alcohols, mono- and disaccharides in the presence of LiCl, ESI positive, cone voltage: 70 V.

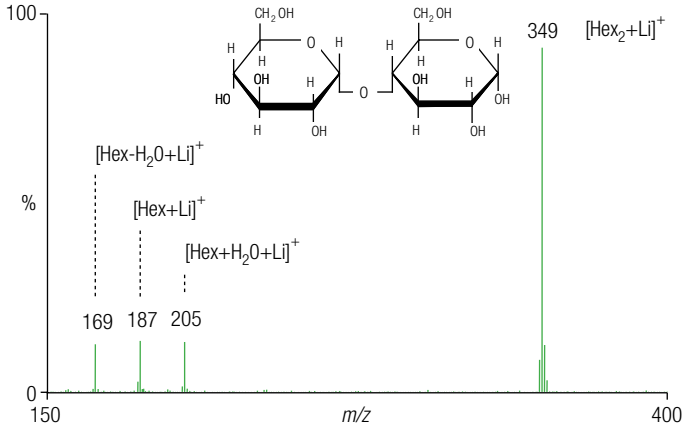

Figure 1-8. Mass spectrum of maltose in the presence of LiCl, ESI positive, cone voltage: 70 V. The carbohydrates are detected as the lithium adducts [M+7]+ in ESI positive mode. In-source fragmentation or collision-induced dissociation can also be used to form characteristic fragment ions, in the mass spectrum of maltose.

Did You Know?

- A pinch of sugar on the tongue is a traditional remedy for hiccups.
- A teaspoon of sugar after a hot curry helps relieve that burning feeling in your mouth (although dairy, such as a glass of milk or yogurt, is more effective).

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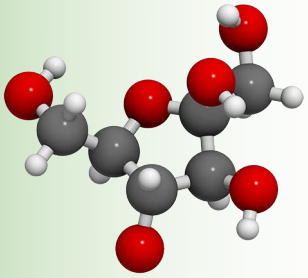
Table of Contents

Chapter 1: Carbohydrates



Fructose structure.

Corn Syrup

Corn syrup is a food syrup, which is made from the starch of corn and contains varying amounts of maltose and larger oligosaccharides, depending on the grade. Corn syrup is used in foods as a thickener, a sweetener, and a humectant, as well as to soften texture, add volume, prevent crystallization of sugar, and enhance flavor.

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Corn Syrup

In this example, analytes in different grades of corn syrup were readily resolved using HPLC-Charged Aerosol Detection using a HILIC column.

Did You Know?

Light corn syrup is clarified and decolorized and usually contains some vanilla for flavor. Dark corn syrup has caramel flavor and coloring added and has a stronger flavor. In cooking they can be used interchangeably, taking into account the stronger flavor of the dark variety.

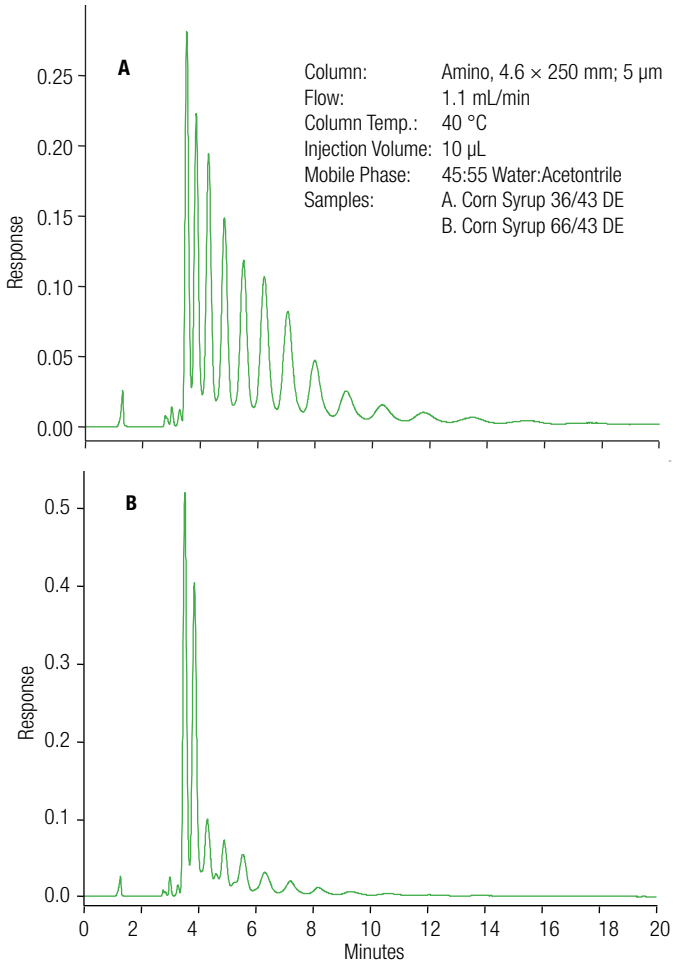

Figure 1-9. Corn syrup 36/43 DE (A) and corn syrup 36/66 (B) by HILIC-Charged Aerosol Detection..

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Chapter 1: Carbohydrates

Chicory flower and powder

Dietary Fiber

Dietary fiber is coarse, indigestible plant matter that, when included in the diet, promotes good gastrointestinal tract health. Typically, dietary fiber is fibrous or gummy material derived from plant cell walls, lignin, polysaccharides, and similar substances that resist hydrolysis by digestive enzymes.

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Dietary Fiber: Inulins

Inulins are a group of naturally occurring polysaccharides composed mainly of fructose. The primary source of inulin used by the food industry is chicory. Inulin belongs to a class of dietary fibers called fructans.

Inulin is often used in processed foods as it has unusually adaptable characteristics. Because it contains a fraction of the energy of simple carbohydrates, it is typically used to replace sugar, fat, and flour in reduced calorie food products.

As shown in Application Note 67 and Application Update 150, HPAE-PAD is very effective at characterizing inulins from different sources.

Trivia Question

Q: Approximately how much dietary fiber does the average American consume on a daily basis?

A: The average American consumes 14 grams of dietary fiber a day, which is considerably less than the recommended level. The 2005 Dietary Guidelines for Americans recommends 14 grams of fiber per 1000 calories consumed.

Column A:	Dionex CarboPac PA100 and guard	Column B:	Dionex CarboPac PA200 and guard
Flow:	1.0 mL/min	Flow:	0.5 mL/min
Temperature:	30 °C	Temperature:	30 °C
Injection Volume:	10 µL	Injection Volume:	5 µL
Eluent:	0 min: 100 mM NaOH/ 150 mM sodium acetate, 60 min: 100 mM NaOH/ 550 mM sodium acetate, curve 6t	Eluent:	0 min: 100 mM NaOH/ 180 mM sodium acetate, 60 min: 100 mM NaOH/ 550 mM sodium acetate, curve 5
Detection:	PAD (Au), Waveform A (TN21)	Detection:	PAD (Au), Waveform A (TN21)
Sample:	Chicory root inulin 5.0 mg/mL in 0.1 M NaOH	Sample:	Chicory root inulin 5.0 mg/mL in 0.1 M NaOH

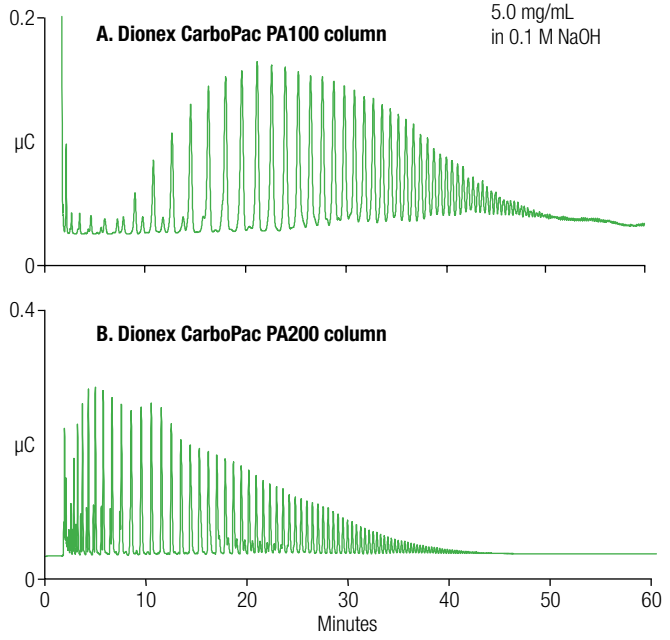

Figure 1-10. HPAE-PAD comparison of the Dionex CarboPac PA100 and PA200 columns for the separation of chicory inulin.

Download Application Note 67: Determination of Plant-Derived Natural Oligo- and Polysaccharides

Download Application Update 150: Determination of Plant-Derived Neutral Oligo- and Polysaccharides Using the Dionex CarboPac PA200

Dietary Fiber: Inulins

Column A: Dionex CarboPac PA100 and guard
Flow: 1.0 mL/min
Temperature: 30 °C
Injection Volume: 10 µL
Eluent: 0 min: 100 mM NaOH/150 mM sodium acetate, 60 min: 100 mM NaOH/ 550 mM sodium acetate, Curve 6
Detection: PAD (Au), Waveform A (TN21)
Sample: 5.5 mg/mL in 0.1 M NaOH

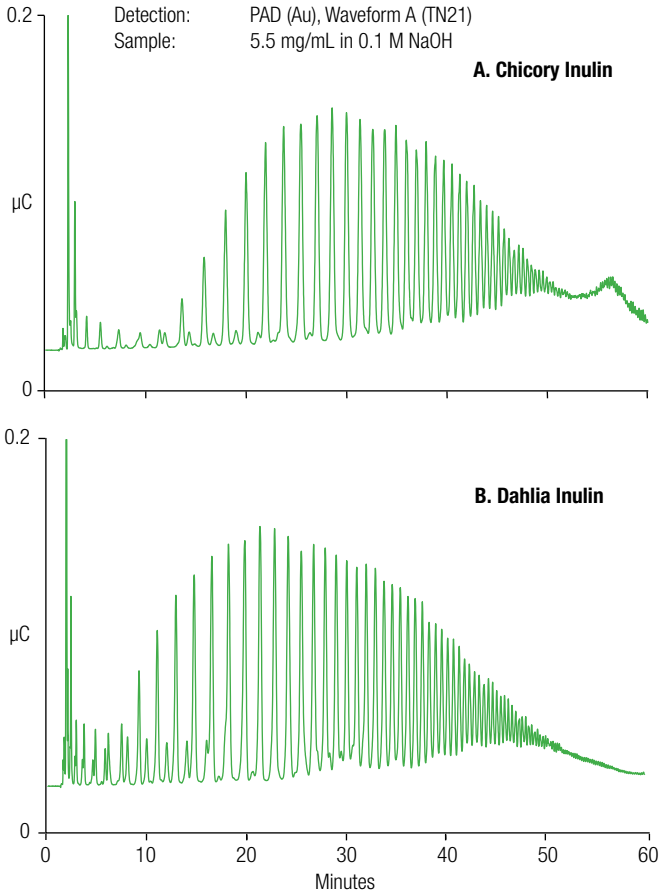

Figure 1-11. HPAE-PAD comparison of chicory and dahlia inulins.

Column A: Dionex CarboPac PA100 and guard
Flow: 1.0 mL/min
Temperature: 30 °C
Injection Volume: 10 µL
Eluent: 0 min at 100 mM sodium hudroxide 150 mM sodium acetate; 60 min at 100 mM NaOH 150 mM sodium acetate Curve 6
Detection: PAD (Au), Waveform A (TN21)
Sample: A. Lot 49F7175 B. Lot 79F7105

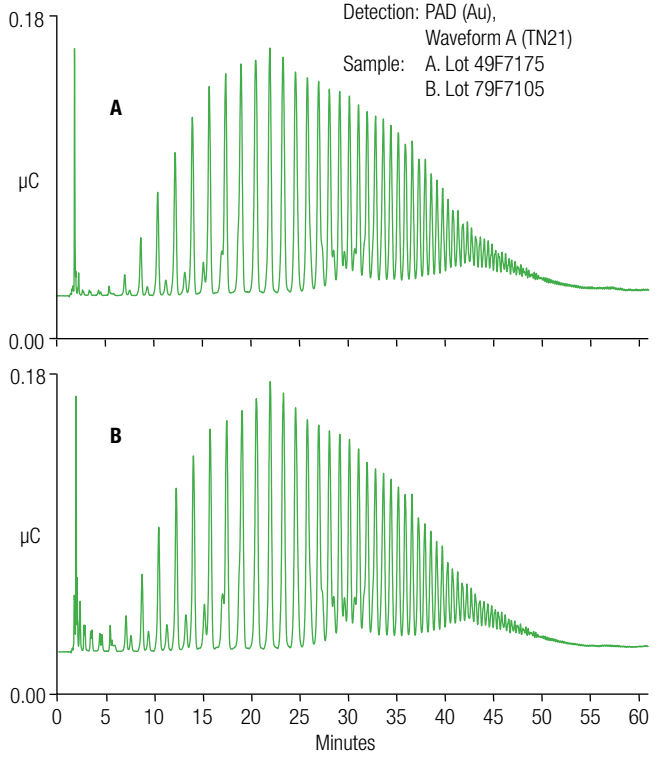

Figure 1-12. HPAE-PAD Comparison of two lots of chicory inulin.

Did You Know?

- Fiber may be beneficial in treating or preventing constipation, hemorrhoids, and diverticulosis.
- Water-soluble fiber helps decrease blood cholesterol levels.

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Dietary Fiber: *Trans*-Galactooligosaccharides

About two-thirds to three-fourths of the dietary fiber in a typical diet is classified as insoluble in an aqueous enzyme solution. Soluble dietary fiber is soluble in an aqueous enzyme system, but can be precipitated with four parts of ethanol to one part of the aqueous mixture. Many soluble dietary fibers are food gums, such as pectins, carrageenan, guar, locust bean gum, gum acacia, and xanthan gum.

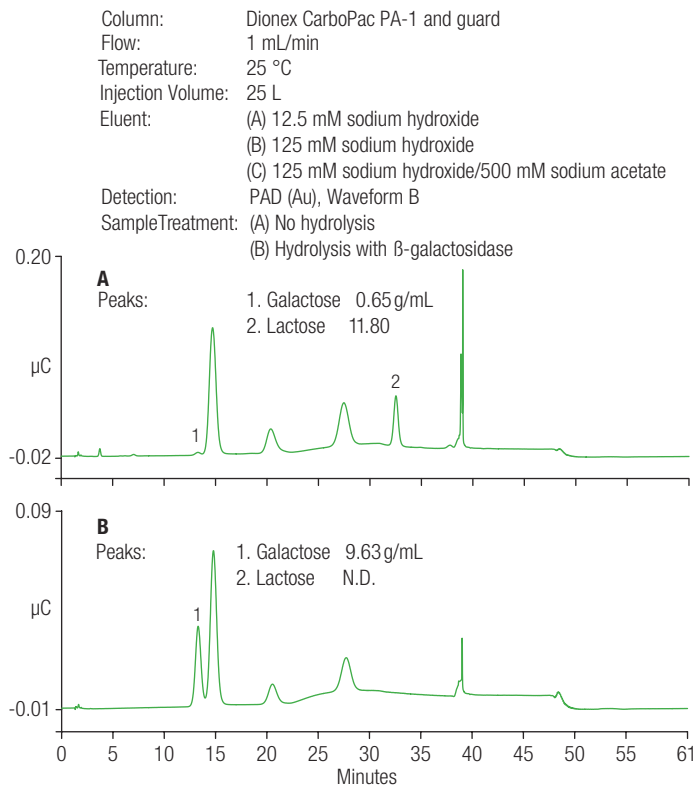

Figure 1-13. HPAE-PAD analysis of lemonade syrup +15% TGOS using Waveform B, before (A) and after hydrolysis (B) with β-galactosidase.

Trans-galactooligosaccharides (TGOS) are soluble galactans that can be classified as dietary fiber because they pass through the small intestine intact, but are fermented in the colon by the intestinal flora. TGOS are di- to octasaccharides composed of 1–7 galactose units linked to a glucose molecule at the reducing end.

Application Note 155 describes a method to measure TGOS in food and feed products based on high performance anion-exchange chromatography with pulsed amperometric detection (HPAE-PAD). This is now an approved as Association of Official Analytical Chemists (AOAC) Method 2001.02.

Table 1-1. TGOS in different food samples

Sample	TGOS (%)
Yogurt Drink #1	5.35
Yogurt Drink #7	5.39
Lemonade Syrup #2	13.10
Lemonade Syrup #11	13.41
Custard #3	3.79
Custard #5	4.19
Orange Juice #4	3.48
Orange Juice #13	3.55
Pet Candy #6	1.92
Pet Candy #14	2.17
Biscuits #8	7.68
Biscuits #12	8.38
Infant Formula #9	4.12
Infant Formula #10	4.76

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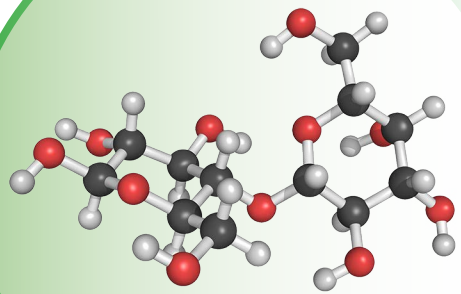
Download Application Note 155: Determination of Trans-Galactooligosaccharides in Foods by AOAC Method 2001.02

Chapter 1: Carbohydrates



Lactose structure

Lactose and Lactulose

Lactose is the major disaccharide found in milk products and it is catabolized by the enzyme lactase, which is deficient in lactose-intolerant individuals. While lactose intolerance is not a dangerous condition, its global prevalence has created a large market for lactose-free products. This has created the need for simple, reliable, and accurate analytical methods to quantify lactose. Lactulose, a disaccharide that does not occur naturally, is formed when milk is sterilized using heat-treatment. It is used as a possible marker of product degradation.

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Lactose in Milk

The AOAC Method 984.15 uses enzymatic hydrolysis of lactose to glucose and galactose at pH 6.6 by β-galactosidase. This method is time consuming, however, and needs extensive reagent preparations. The reported detection limits of this assay may not allow for the determination of lactose in lactose-free samples.

Presented in Application Update 182, is a simple, validated HPLC-Charged Aerosol Detection method for the routine analysis of lactose in milk, reduced-fat milk and lactose-free milk.

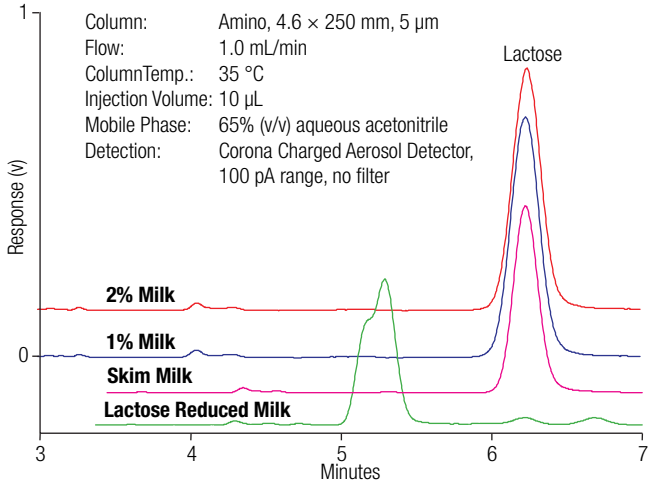

Figure 1-14. Overlay of HPLC-Charged Aerosol Detection chromatograms of different milk samples.

Trivia Question

Q: Lactose intolerance varies considerably amongst various ethnic and racial groups. Can you guess which group exhibits the lowest level of lactose intolerance?

A: Overall US population: 25%

Asian: 90%

African-American: 80%

Hispanic: 70%

Caucasian: 15%

Lactose and Lactulose in Milk

Milk changes structurally and chemically when heat treated, but the extent of the change depends on the temperature and duration of the heating. Lactulose is a disaccharide containing galactose and fructose that is not naturally found in raw milk but is formed during the heat treatment of milk by the isomerization of lactose. Lactulose levels in milk can be used to determine the method that was used to sterilize the milk. The average lactulose content when using in-container sterilization is 744 mg/L, but only 3.5 mg/L in milk treated by low temperature pasteurization methods.

Application Note 248 describes a sensitive and accurate method to determine lactose and lactulose in dairy products, including lactose-free products, using HPAE-PAD.

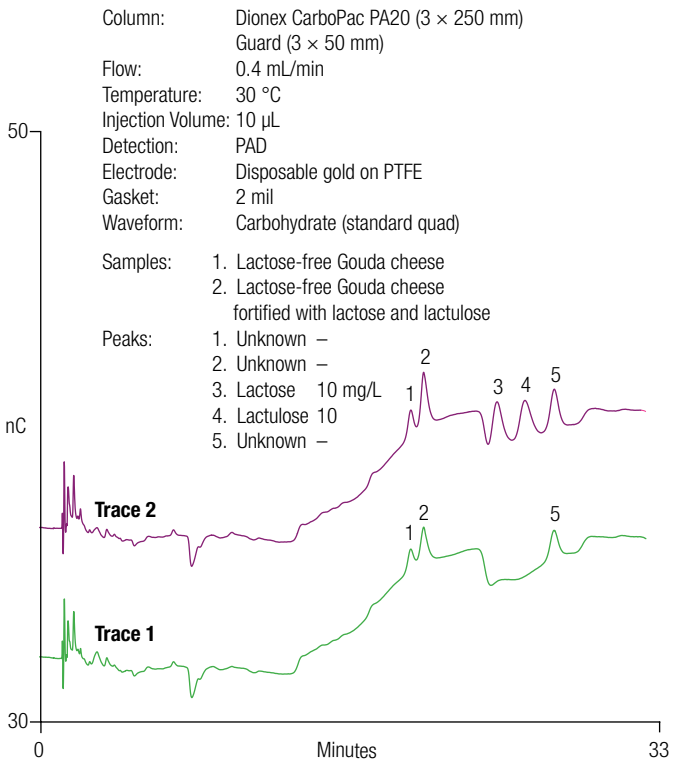

Figure 1-15. Separation of carbohydrates in fortified and unfortified lactose-free Gouda cheese samples.

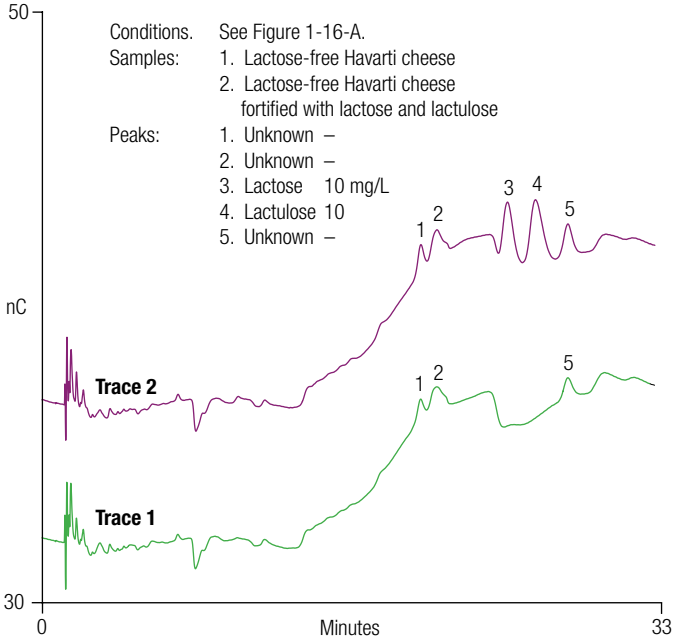

Figure 1-16. Separation of carbohydrates in fortified and unfortified lactose-free Havarti cheese samples.

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Download Application Note 248: Determination of Lactose in Lactose-Free Milk Products by HPAE-PAD

Lactose and Lactulose in Milk

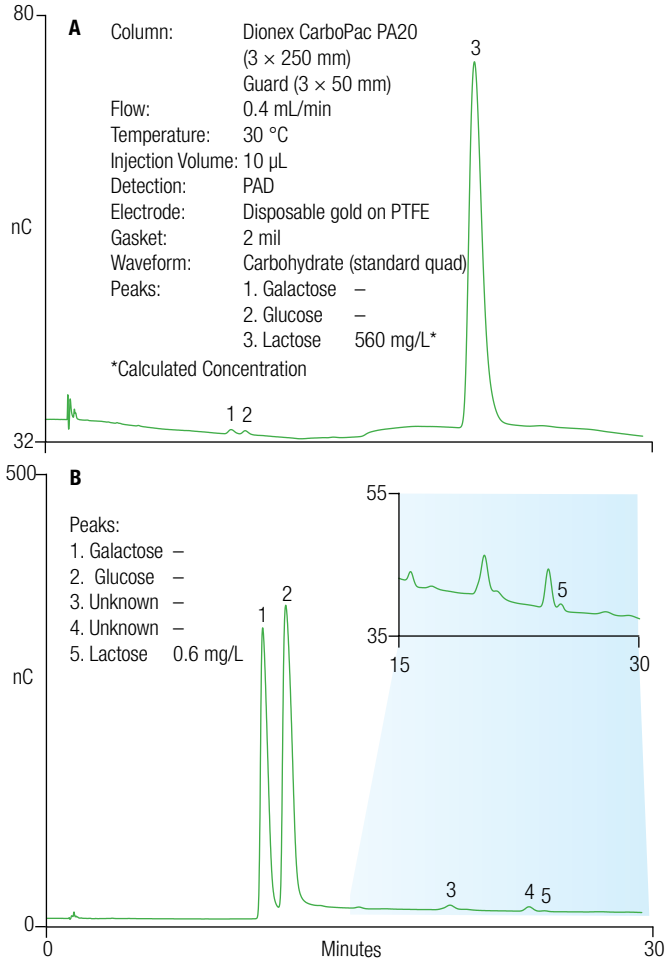

Figure 1-17. A bi-panel showing the following chromatograms: A) separation of carbohydrates in whole milk, and B) separation of carbohydrates in lactose-free low-fat milk.

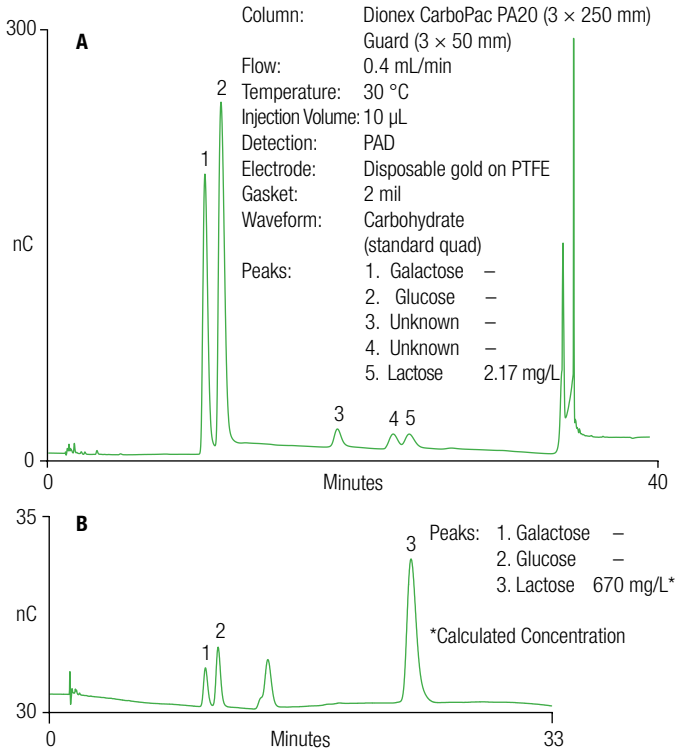

Figure 1-18. A bi-panel showing the following chromatograms: A) separation of carbohydrates in lactose-free low-fat cottage cheese, and B) separation of carbohydrates in 1:20 diluted low-fat yogurt.

Did You Know?

- Hippopotamus milk is bright pink due to the presence of two kinds of unique acids called "Hipposudoric acid" and "Norhipposudoric acid".
- Camel's milk does not curdle.
- A cow spends about 6 hours eating and 8 hours chewing its cud every day. That's almost 30,000 chews daily!

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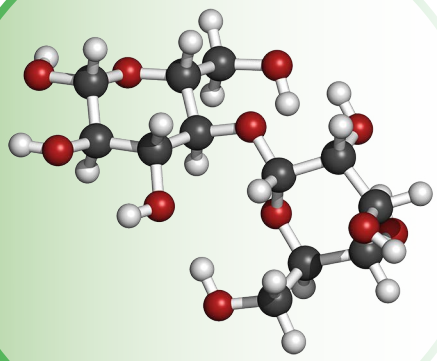
Chapter 1: Carbohydrates



Maltose structure

Maltodextrins

Maltodextrin, a polysaccharide produced by the hydrolysis of starch, is used as a food additive. Maltodextrin is easily digestible, being absorbed as rapidly as glucose. It can be found as an ingredient in a variety of processed foods, sodas and candy.

Maltodextrin is sometimes used by the beer industry to increase the specific gravity of the final product to improve the mouthfeel, increase head retention, and to reduce the dryness of the drink.

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Maltodextrins

A given maltodextrin is not one compound but rather a suite of polysaccharide of varying chain lengths (affected by the extent of hydrolysis). The determination of maltodextrins by HPAE-PAD is described in Application Note 67 and the updated method in Application Update 150.

Column A:	Dionex CarboPac PA100 and guard
Flow:	1.0 mL/min
Temperature:	30 °C
Injection Volume:	10 µL
Eluent:	0 min: 100 mM NaOH/ 150 mM sodium acetate, 60 min: 100 mM NaOH/ 550 mM sodium acetate, curve 6
Detection:	PAD (Au), Waveform A (TN21)
Sample:	MALTRIN® M040, 5 mg/mL in water

Maltrin is a registered trademark of Grain Processing Corporation

Column B:	Dionex CarboPac PA200 and guard
Flow:	0.5 mL/min
Temperature:	30 °C
Injection Volume:	5 µL
Eluent:	0 min: 100 mM NaOH/ 180 mM sodium acetate, 60 min: 100 mM NaOH/ 450 mM sodium acetate, curve 5
Detection:	PAD (Au), Waveform A (TN21)
Sample:	Maltrin M040, 5 mg/mL in water
Peaks:	3. Maltotriose

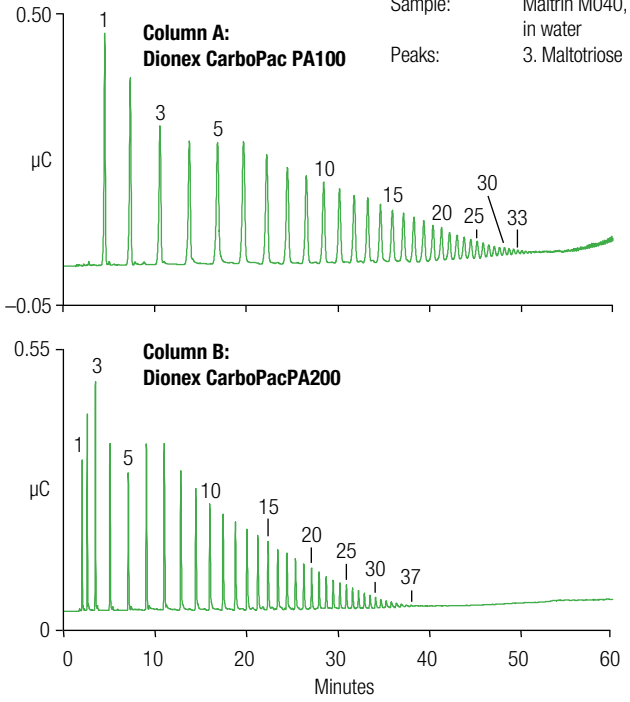

Figure 1-19. Comparison of the Dionex CarboPac PA100 and PA200 columns for the separation of maltodextrins, showing improved resolution by the Dionex CarboPac PA200 column.

Download Application Note 67: Determination of Plant-Derived Natural Oligo- and Polysaccharides

Download Application Update 150: Determination of Plant-Derived Neutral Oligo- and Polysaccharides Using the Dionex CarboPac PA200

Maltodextrins

Column A:	Dionex CarboPac PA100 and guard	Column B:	Dionex CarboPac PA200 and guard
Flow:	1.0 mL/min	Flow:	0.5 mL/min
Temperature:	30 °C	Temperature:	30 °C
Injection Volume:	20 µL	Injection Volume:	5 µL
Eluent:	0 min: 150 mM NaOH/ 50 mM sodium acetate, 60 min: 150 mM NaOH/ 450 mM sodium acetate, curve 6	Eluent:	0 min: 100 mM NaOH/ 70 mM sodium acetate, 30 min: 100 mM NaOH/ 300 mM sodium acetate, curve 4
Detection:	PAD (Au), Waveform A (TN21)	Detection:	PAD (Au), Waveform A (TN21)
Sample:	Red Hook Amber Ale 1:50 dilution	Sample:	Red Hook Amber Ale 1:50 dilution

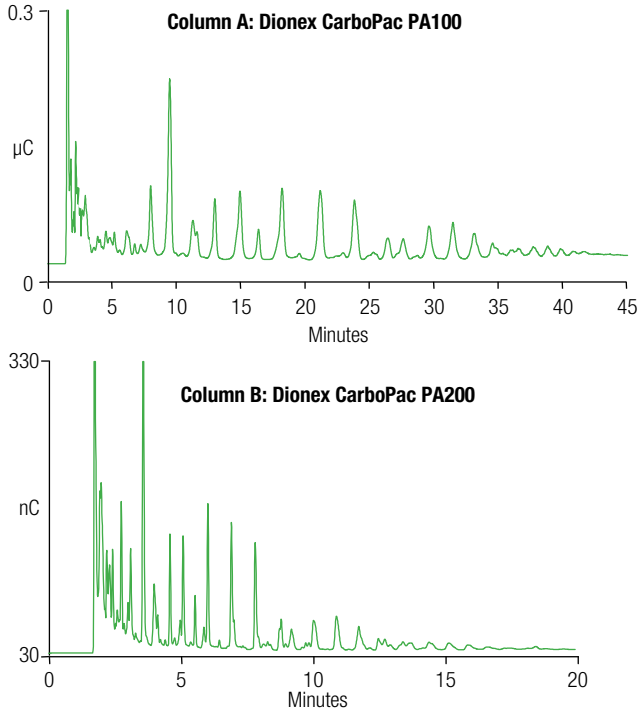

Figure 1-20. Comparison of the Dionex CarboPac PA100 and PA200 columns for the separation of maltodextrins in beer, showing improved resolution by the Dionex CarboPac PA200 column.

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Maltodextrins

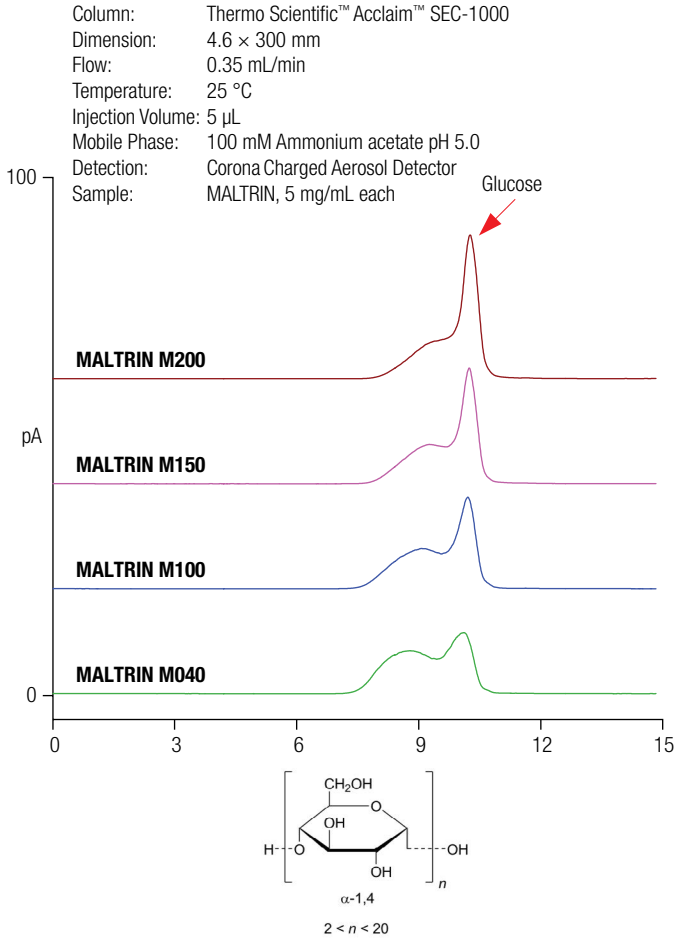

Figure 1-21. Maltodextrin samples with different degrees of hydrolysis are clearly differentiated using the HPLC-Charged Aerosol Detection and an Acclaim SEC-1000 column. The higher the maltrin number, the greater the degree of hydrolysis – reflected by the relative increase in concentration of glucose and the increase in retention time of the polymer.

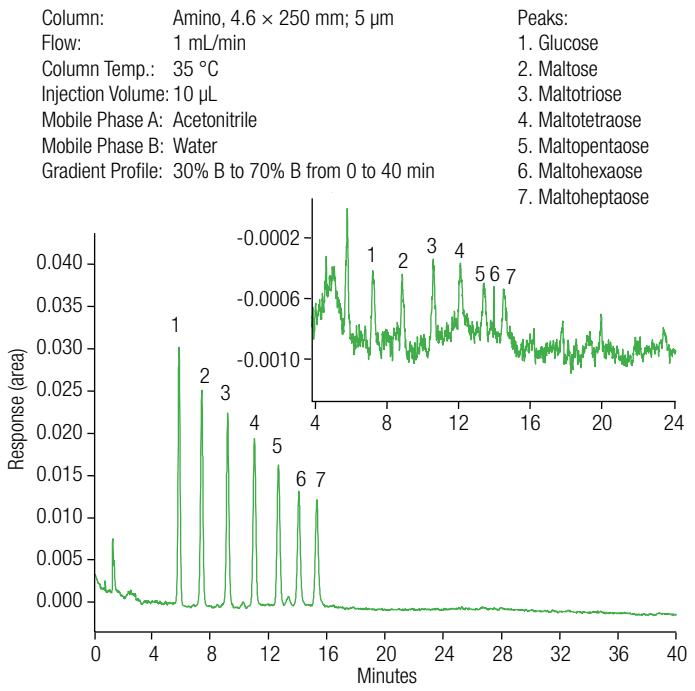

Figure 1-22. Low MW maltodextrins analyzed by HILIC-Charged Aerosol Detector (200 ng on column). Inset: 5 ng on column.

Chapter 1: Carbohydrates

Infant formula

Sialic Acids

Dietary sialic acids play an important role in infant development, serving both immune system and cognitive development roles. Key neuraminic acids in human milk differ in abundance to those in bovine milk. In addition, bovine milk has been shown to contain less than 25% of the total sialic acid content of human milk. The sialic acid content in unfortified infant formulas is dependent on the sialic acids from bovine milk. As such, these formulas have lower sialic acid contents and different sialic acid proportions compared to human milk. Because of the critical role these carbohydrates play in infant development, many manufacturers enrich infant formulas with sialic acids to more closely mimic human milk.

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Sialic Acids

Sialic acid determination in a complex matrix, such as a dairy product, presents many challenges. The majority of milk sialic acids are found as part of a glycoconjugate rather than as the free acid. In order to determine the sialic acids, they must first be released from the glycoproteins, glycolipids, and oligosaccharides.

In dairy products, this is typically accomplished by hydrolysis. Following sample hydrolysis, sialic acids can be determined by either HPAE-PAD, as shown in Application Note 253, or HPLC with fluorescence detection, as shown in Application Note 266.

Column: Dionex CarboPac PA20 guard, 3 × 30 mm
Dionex CarboPac PA20, 3 × 150 mm
Temperature: 30 °C
Flow: 0.5 mL/min
Injection Volume: 10 µL
Eluent: 10–200 mM acetate in 100 mM NaOH from 0–15 min, 200 mM acetate in 100 mM NaOH from 15–20 min, 10 mM acetate in 100 mM NaOH from 20–25 min
Detection: PAD, Au (Disposable)
Sample Prep.: Acid hydrolysis, 1 h at 80 °C in 50 mM H_2SO_4 followed by enzyme digestion of maltodextrins
Samples: Brands A and B

Peaks:		A	B
1.	Neu5Ac	9.1	3.0 pmol
2.	Neu5Gc	0.44	0.41

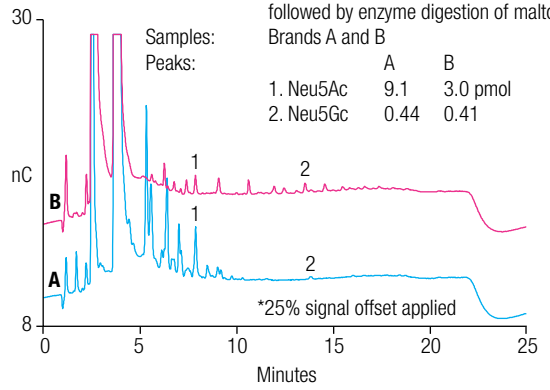


Figure 1-23. Determination of sialic acids in infant formula samples based on A) dairy, B) dairy with added maltodextrins, using HPAE-PAD.

Column: Acclaim RSLC 120 C18 2.2 µm, 2.1 × 100 mm
Flow: 0.42 mL/min
Temperature: 45 °C
Injection Volume: 5 µL
Eluent A : DI water
Eluent B: Acetonitrile
Gradient: 5% B for 5 min, 5%–20% B in 6 min, 20%–40% B in 2 min, 40% A for 5 min.
3 min equilibration before injection at 5% B
Detection: Fluorescence, emission 373 nm, excitation 448 nm
Sample: Infant Formulas A, B, and C
Sample Prep.: Anion exchange followed by DMB derivatization

Peaks:		A	B
1.	Neu5Gc	1.9	1.4 pmol
2.	Neu5Ac	72	49
3.	Reagent Peak	—	—
4.	Neu5,7Ac2	—	—
5.	Neu5,9Ac2	—	—

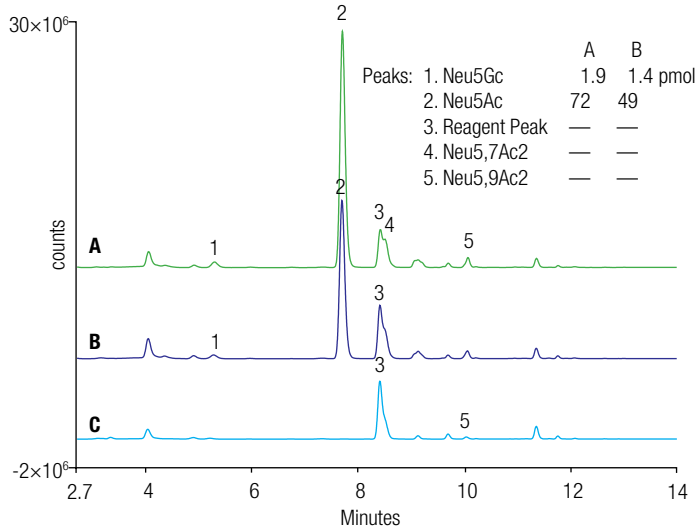


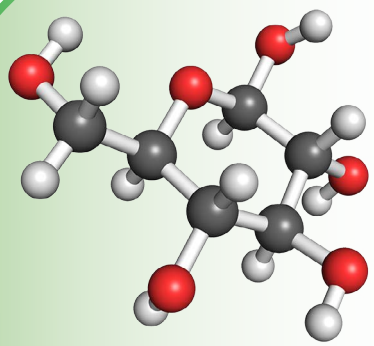
Figure 1-24. Determination of sialic acids in infant formulas using HPLC-FLD.

Download Application Note 253: HPAE-PAD Determination of Infant Formula Sialic Acids

Download Application Note 266: Determination of Sialic Acids Using UHPLC with Fluorescence Detection

Table of Contents

Chapter 1: Carbohydrates



Glucose structure

Simple Carbohydrates: Beverages

Simple carbohydrates, sometimes called sugars, include a number of mono- and disaccharides. They are rapidly catabolized by the body to be used as energy. Simple carbohydrates are found naturally in foods such as fruits, milk, and milk products. They are also found in processed and refined sugars such as table sugar, syrups, candy, and sodas.

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Simple Carbohydrates: Beverages

Column:	Anion Exchange, 4.6 × 250 mm, 7 µm
Flow:	Isocratic at 1.50 mL/min. with constant He purge
Mobile Phase:	100 mM sodium hydroxide (NaOH), prepared from pellets, 99.99%, semiconductor grade
EC Detector:	Coulochem III, model 5040 cell with Au Target, 25 µm Mylar
EC Parameters:	E1 +200 mV 500 ms AD 300 ms E2 -1000 mV 10 ms E3 +600 mV 1 ms E4 -100 mV 10 ms
Peaks:	1. Glucose 2. Fructose

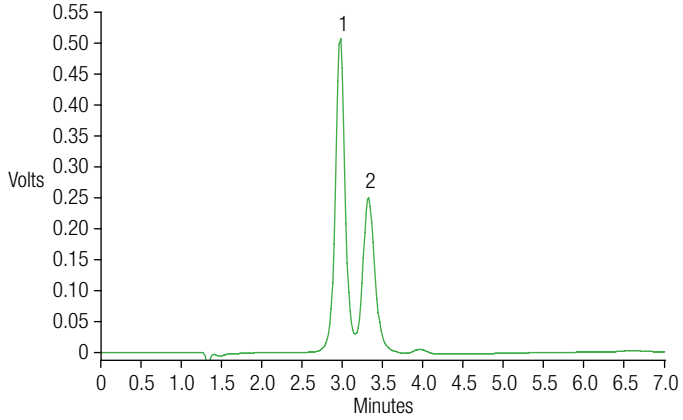

Figure 1-25. Chromatogram of cola soda.

Did You Know?

According to the Beverage Marketing Corporation, the average American drinks approximately 44.7 gallons of soda a year. That's equivalent to approximately 487 cans of soda, or 85 2-liter bottles!

Column:	Anion Exchange, 4.6 × 250 mm, 7 µm
Flow:	Isocratic at 1.50 mL/min. with constant He purge
Mobile Phase:	100 mM sodium hydroxide (NaOH), prepared from pellets, 99.99%, semiconductor grade
EC Detector:	Coulochem III, model 5040 cell with Au Target, 25 µm Mylar
EC Parameters:	E1 +200 mV 500 ms AD 300 ms E2 -1000 mV 10 ms E3 +600 mV 1 ms E4 -100 mV 10 ms

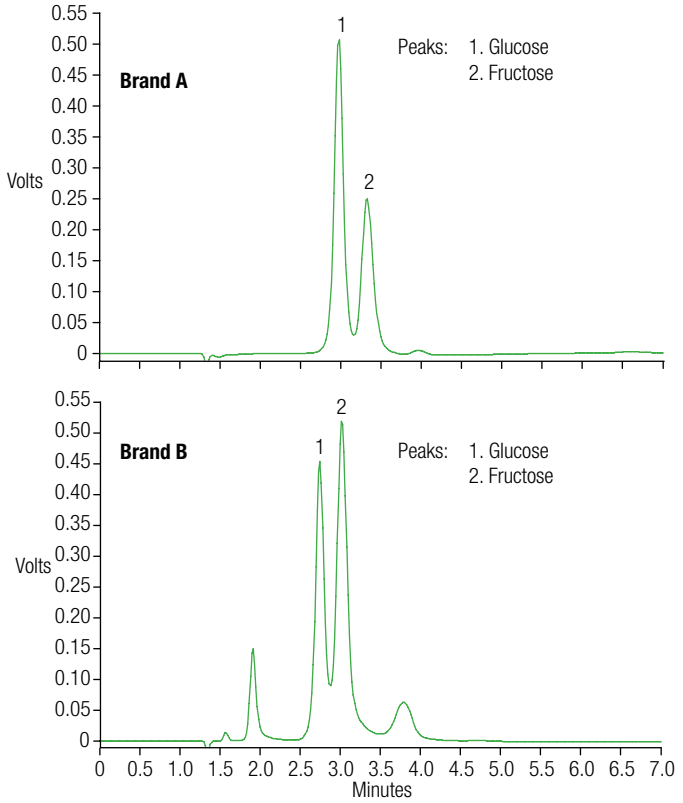

Figure 1-26. Chromatograms of apple juice Brands A and B.

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Simple Carbohydrates: Beverages

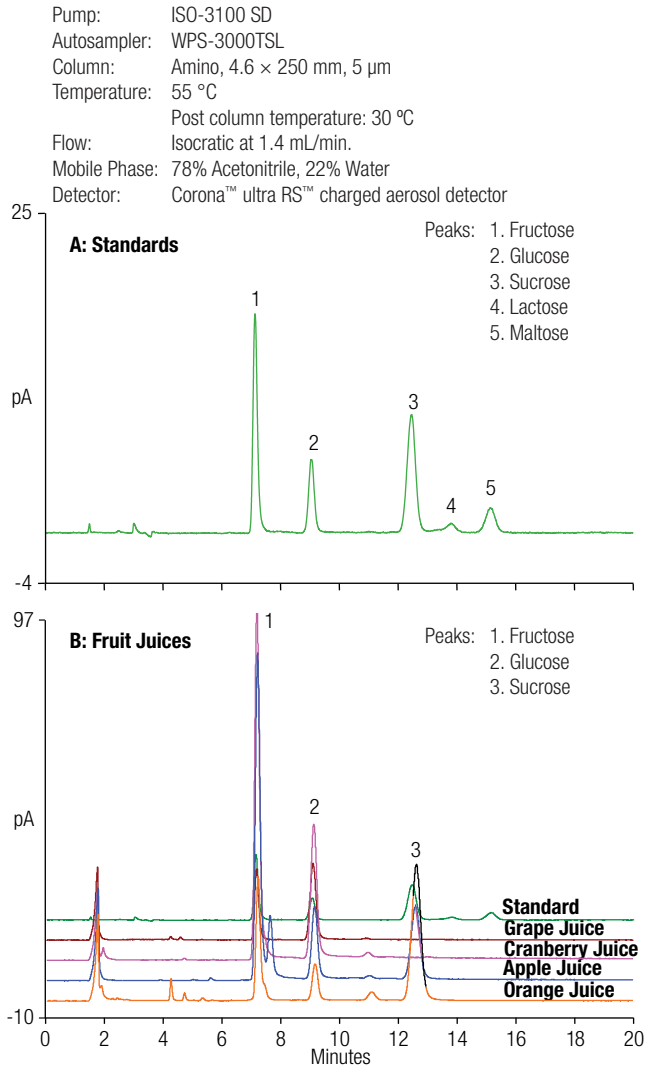

Figure 1-27. (A) Analysis of standards and (B) analysis of fruit juices.

Did You Know?

- A sugar mill crushes (mills) the sugarcane stalks and squeezes the juice from the plant. The juice is crystallized into a product called raw sugar. A refinery takes the raw sugar and converts it into food-grade white sugar.
- Sugarcane was discovered by Alexander the Great in 327 BC. Christopher Columbus introduced sugar to the New World in 1493 on his second voyage.

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Simple Carbohydrates: Beverages

HPLC-CAD

The major ingredients in most sports beverages are sugar and salt. In this product, the sugar is high-fructose corn syrup. The Thermo™ Scientific™ Acclaim™ Trinity™ P2 column is the latest member of the Trinity family that is designed to resolve a broad range of anions and cations, mono- or multi-valent and uncharged (neutral) compounds, in a single sample injection using a simple gradient method. The Acclaim Trinity P2 column can also be used in HILIC mode for analysis for hydrophilic neutral substances such as the simple sugars shown here. The Corona Veo detector provides sensitive, convenient detection of inorganic ions and nonvolatile sugars.

LC System:	UltiMate 3000 RS
Column:	Acclaim Trinity P2, 3 µm
Dimensions:	3.0 × 50 mm
Flow:	0.60 mL/min
Temperature:	60 °C
Injection Volume:	5 µL
Mobile Phases:	A: Acetonitrile B: 100 mM Ammonium formate, pH 3.65
Isocratic:	80% A / 20% B
Detector:	Corona Veo charged aerosol (evaporator 55 °C, data rate 5 Hz, filter 2 sec, power function 1.5)
Sample:	Sports drink
Sample Prep:	Decolorized with Thermo Scientific™ Dionex™ OnGuard™ II P cartridge, diluted 40× in mobile phase
Peaks:	1. Fructose 2. Glucose 3. Chloride 4. Maltose 5. Sodium

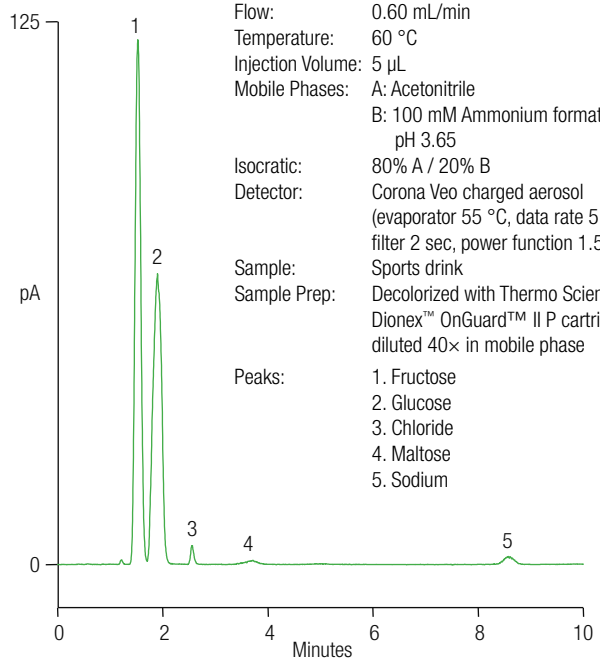

Figure 1-28. Sugars in a sports beverage using an Acclaim Triity P2 column in HILC mode.

Table of Contents

Simple Carbohydrates: Beverages

Column:	Dionex CarboPac PA20 set, 0.4 × 150 mm
Flow:	0.008 mL/min
Column Temp.:	30 °C
Injection Volume:	0.4 µL
Eluent Source:	Thermo Scientific Dionex EGC Eluent Generator Cartridge (Capillary)
Eluent:	10 mM KOH (-7 to 20 min)
Detection:	PAD, Au disposable, 0.001" gasket, 4-Potential Carbohydrate waveform
Ref. Electrode:	Ag/AgCl
Sample Prep.:	5000-fold dilution, degas

Peaks:	mg/L	Total	%
1. Glucose	10	50 g/L	32
2. Fructose	21	105	68

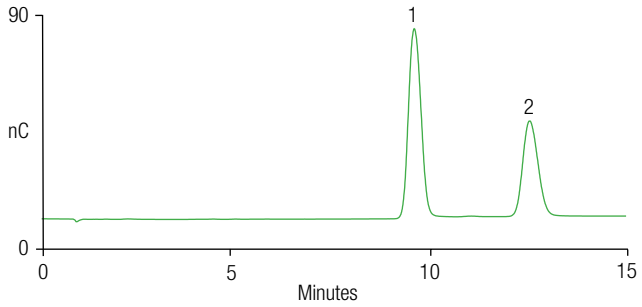

Figure 1-29. Glucose and fructose in a carbonated beverage by capillary HPAE-PAD.

Column:	Dionex CarboPac PA20 set, 0.4 × 150 mm
Flow:	0.008 mL/min
Column Temp.:	30 °C
Inection. Volume:	0.4 µL
Eluent Source:	Dionex EGC-KOH Cartridge (Capillary)
Eluent:	10 mM KOH (-7 to 20 min)
Detection:	PAD, Au disposable, 0.015" gasket, 4-Potential Carbohydrate waveform
Ref. Electrode:	Ag/AgCl
Sample Prep.:	Two-fold dilution, degas

Peaks:	mg/L	Total	%
1. Void Volume			
2. Glucose	120	0.24 g/L	41
3. Sucrose	50	0.10	17
4. Fructose	125	0.25	42

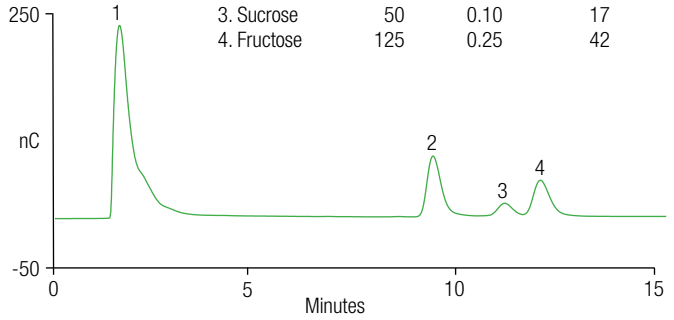

Figure 1-30. A low-sugar dragon fruit beverage by capillary HPAE-PAD.

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Download Technical Note 135: Determinations of Monosaccharides and Disaccharides in Beverages by Capillary HPAE-PAD

Simple Carbohydrates: Beverages

Column:	Dionex CarboPac PA20 set, 0.4 × 150 mm
Flow:	0.008 mL/min
Column Temp.:	30 °C
Injection Volume:	0.4 µL
Eluent Source:	Dionex EGC-KOH Cartridge (Capillary)
Eluent:	10 mM KOH (-7 to 20 min)
Detection:	PAD, Au disposable, 0.001" gasket, 4-Potential Carbohydrate waveform
Ref. Electrode:	Ag/AgCl
Sample Prep.:	10,000-fold dilution

Peaks:	mg/L	Total	% Ratio
1. Glucose	4.6	46 g/L	39
2. Sucrose	1.3	13	11
3. Fructose	5.9	59	5

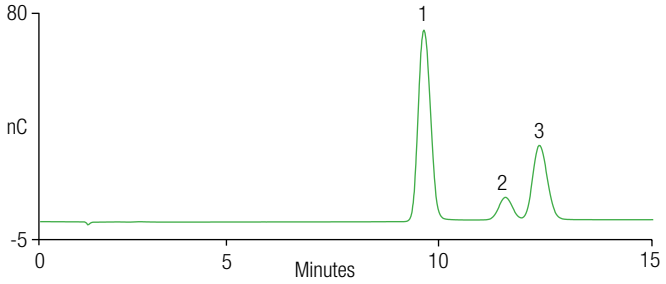

Figure 1-31. Glucose, sucrose, and fructose in a tea beverage by capillary HPAE-PAD.

Column:	Dionex CarboPac PA20 set, 0.4 × 150 mm
Flow:	0.008 mL/min
Column Temp.:	30 °C
Injection Volume:	0.4 µL
Eluent Source:	Dionex EGC-KOH Cartridge (Capillary)
Eluent:	10 mM KOH (-7 to 20 min)
Detection:	PAD, Au disposable, 0.001" gasket, 4-Potential Carbohydrate waveform
Ref. Electrode:	Ag/AgCl
Sample Prep.:	10,000-fold dilution

Peaks:	mg/L	Total	% Ratio
1. Void Volume			
2. Galactose	< 0.02	— g/L	—
3. Glucose	11	55	32
4. Mannose	0.4	2	1
5. Sucrose	3.4	17	10
6. Fructose	20	100	57

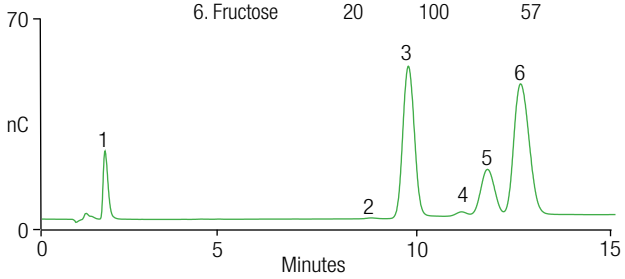

Figure 1-32. Diluted apple cider by capillary HPAE-PAD.

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Simple Carbohydrates: Beverages

Column:	Dionex CarboPac PA20, 0.4 × 150 mm
Flow:	10 µL/min
Temperature:	30 °C
Injection Volume:	0.40 µL
Eluent:	50 mM potassium hydroxide (EG)
Detection:	PAD, 4–potential carbohydrate, Au
Ref. Electrode:	PdH
Gasket Thickness:	25 µm
Samples:	Juice samples (5000× dilution) Standard (20 µM)
Peaks:	1. Glucose 2. Fructose 3. Sucrose

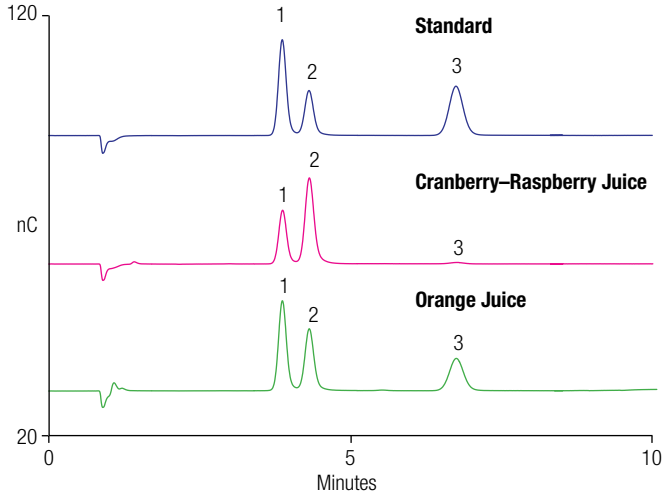

Figure 1-33. Analysis of juices for carbohydrates by capillary HPAE-PAD.

Did You Know?

- Lemons contain more sugar than strawberries.
- Sugar hardens asphalt. It slows the setting of ready-mixed concrete and glue.
- During World War II, only 8 oz. of sugar was allowed to be bought per person per week in the United States and United Kingdom, as part of the rations.

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Simple Carbohydrates: Beverages

In Application Note 280 presents analysis of different coffee samples using AOAC method 995.13 as well as a new, fast IC method capable of resolving the critical analytes up to ten times faster.

Column:	Dionex CarboPac PA1 Analytical (4 × 250 mm),
Flow:	1.0 mL/min
Temperature:	15 °C
Injection Volume:	10 µL
	Dionex CarboPac PA1 Guard (4 × 50)
Eluent:	DI water from 0–50 min
	300 mM NaOH from 50–65 min
	DI water from 65–80 min (re-equilibration)
Detection:	PAD (Au)
Postcolumn Reagent:	300 mM Hydroxide
PCR Flow Rate:	0.6 mL/min
Traces:	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

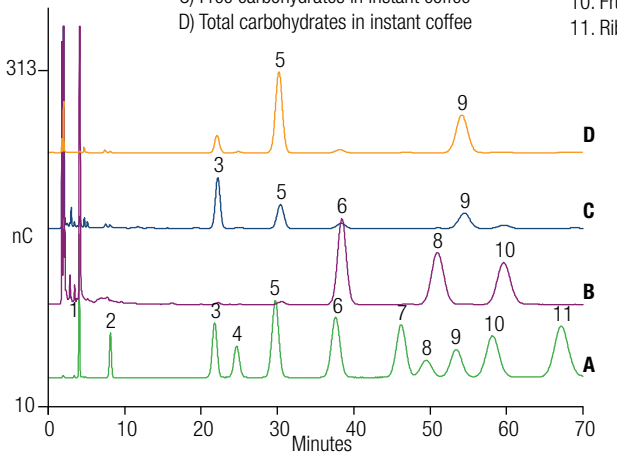

Figure 1-34. Chromatograms of mixed coffee carbohydrate standards (A), free carbohydrate in extract of green coffee beans (B), free carbohydrates in instant coffee (C), and total carbohydrates in instant coffee (D); using the modified AOAC Official Method 995.13 (T = 15 °C).

Column:	Dionex CarboPac PA1 Analytical (4 × 250 mm),
	Dionex CarboPac PA1 Guard (4 × 50)
Flow:	1.0 mL/min
Temperature:	25 °C
Injection Volume:	10 µL
Eluent:	10 mM NaOH 0–6 min, DI water 6–50 min
	300 mM NaOH from 50–65 min,
	DI water from 65–80 min (re-equilibration)
Detection:	PAD (Au)
Postcolumn Reagent:	300 mM Hydroxide
PCR Flow Rate:	0.6 mL/min
Traces:	A) Free carbohydrates extract
	B) Total carbohydrates extract
	C) Mix of standards

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

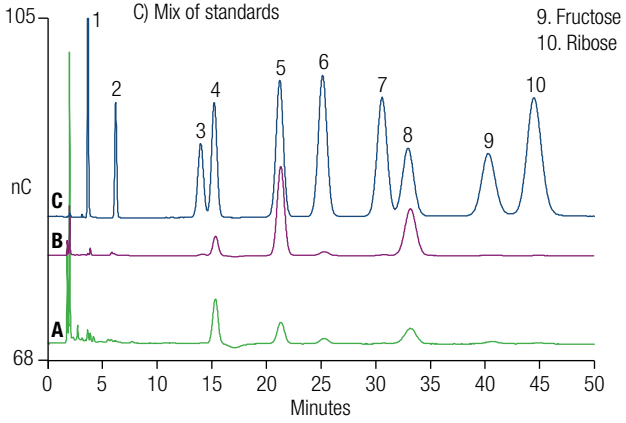

Figure 1-35. Chromatograms of free carbohydrates extract from instant coffee (A), total carbohydrates extract from instant coffee (B), and mixed carbohydrate standards (C); using the modified AOAC Official Method 995.13 (10 mM hydroxide for 6 min, and sucrose not included in mix of standards).

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Download Application Note 280: Carbohydrate in Coffee: AOAC Method 995.12 vs a New Fast Ion Chromatography Method

Simple Carbohydrates: Beverages

Column:	Dionex CarboPac PA1 Analytical (4 × 250 mm), Dionex CarboPac PA1 Guard (4 × 50)
Flow:	1.0 mL/min
Temperature:	25 °C
Injection Volume:	10 µL
Eluent:	10 mM NaOH 0–6 min DI water 6–50 min 300 mM NaOH from 50–65 min DI water from 65–80 min (re-equilibration)
Detection:	PAD (Au)
Postcolumn Reagent:	300 mM Hydroxide
PCR Flow Rate:	0.6 mL/min
Traces:	A) Mix of standards B) Green coffee extract

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

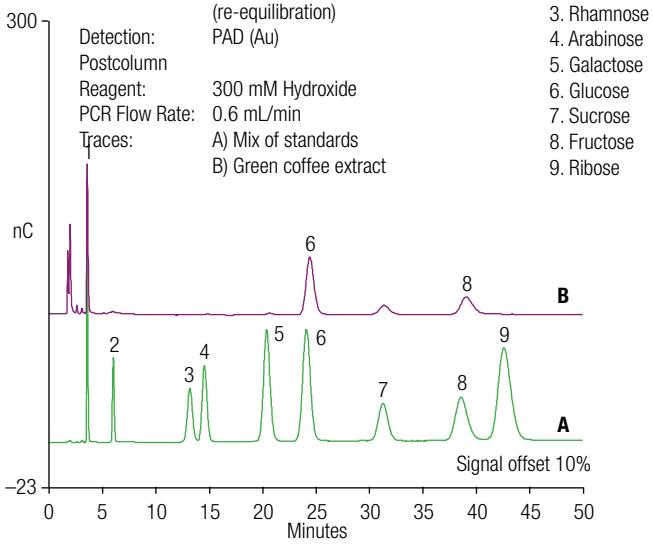

Figure 1-36. Chromatograms of mixed coffee carbohydrate standards (A), free carbohydrates extract from green coffee beans (B); using the modified AOAC Official Method 995.13 (10 mM hydroxide for 6 min, and xylose and mannose not included in mix of standards).

Peaks (mg/mL)	Standard (A)	Instant Free (D)	Instant Total (C)	Green (B)
1. Mannitol	—	0.017	0.006	0.054
2. Fucose	0.040	0.001	—	—
3. Sucrose	0.046	—	—	0.315
4. Arabinose	0.042	0.041	0.126	—
5. Rhamnose/Galactose	—	—	—	—
6. Glucose	0.047	—	0.032	0.059
7. Xylose	0.045	—	—	—
8. Mannose	0.041	0.028	0.603	0.001
9. Fructose/Ribose	—	—	—	—

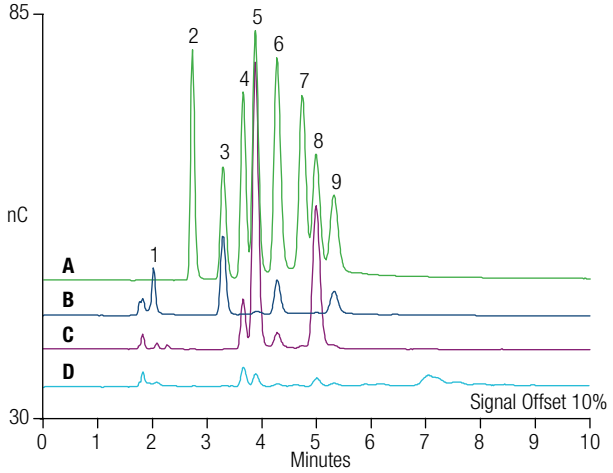

Figure 1-37. Chromatograms of a mixture of coffee carbohydrate standards (A), free carbohydrates from green coffee beans (B), free carbohydrates (C), and total carbohydrates (D) extract from instant coffee; using the fast method.

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Simple Carbohydrates: Beverages

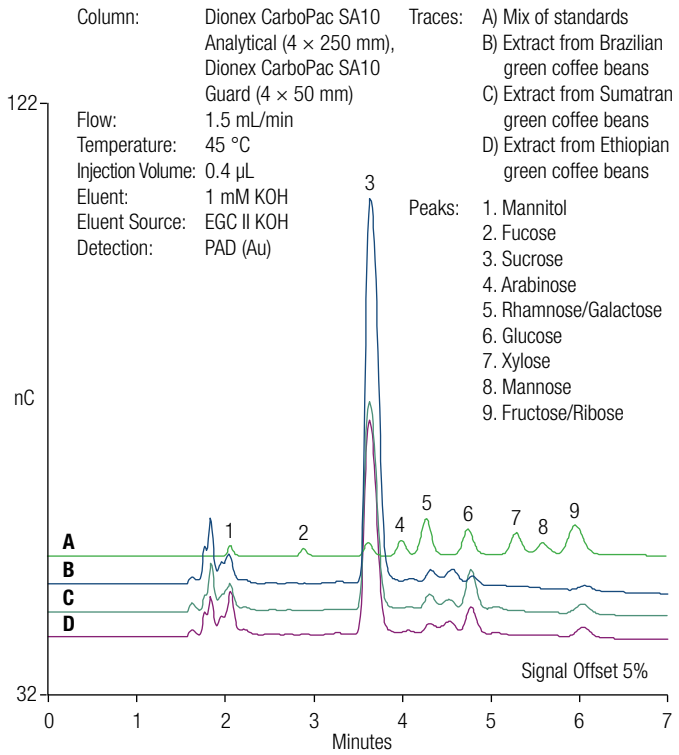

Figure 1-38. Chromatograms of a mix of coffee carbohydrate standards (A), free carbohydrates in green coffee beans, Brazilian beans (B), Sumatran beans (C), and Ethiopian beans (D).

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Simple Carbohydrates: Beverages

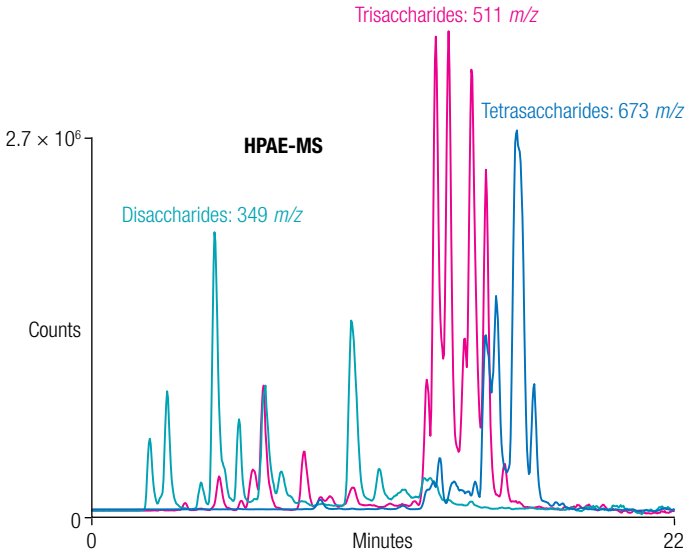

Figure 1-39. Extracted mass chromatograms of carbohydrates in a degassed lager beer sample, separated using a Dionex CarboPac PA200 (3 × 250 mm) column.

Table of Contents

Chapter 1: Carbohydrates

Honeycomb

Simple Carbohydrates: Honey

Honey is the original sweetening agent known from ancient times. The sugars in honey are mainly fructose and glucose, with a scattering of other less common saccharides.

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Simple Carbohydrates: Honey

HILIC-RI

For measuring the main components in honey, the refractive index detector is convenient.

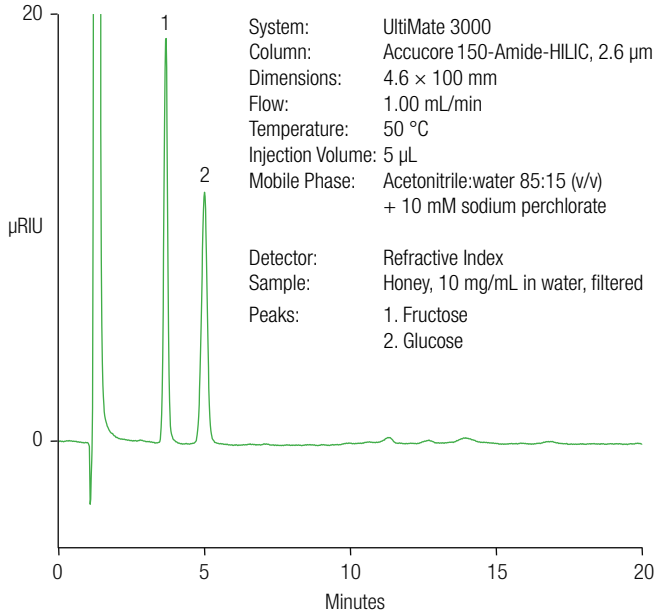

Figure 1-40. HILIC-RI method for determining carbohydrates in honey.

Trivia Question

Q: What is the average lifespan for a worker honey bee?

A: The typical worker honey bee, a sterile female, lives for about 42–45 days. The typical load of pollen collected by a bee weighs approximately 10 mg, obtained from ~1500 flowers growing in a ~12 square mile area. To make one pound of honey, bees must visit two million flowers and fly over 55,000 miles. In her entire life, a worker bee gathers 1/10 tsp of honey.

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Simple Carbohydrates: Honey

HILIC-Charged Aerosol Detection

This approach is much more sensitive than HILIC-RI and can be used to quantitate the less common saccharides.

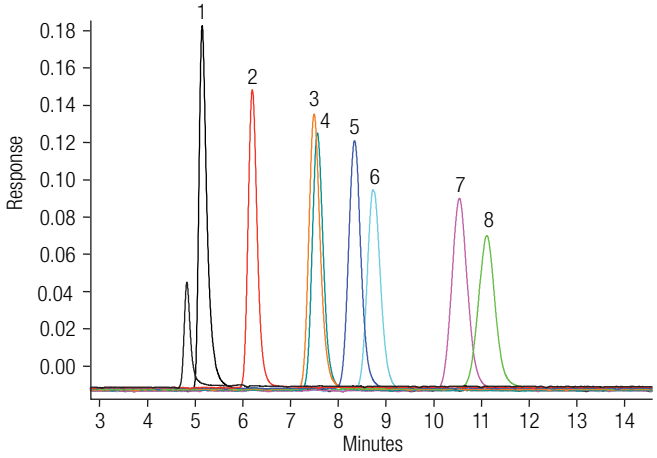

Figure 1-41. HILIC-Charged Aerosol Detection method for determining sugars in honey.

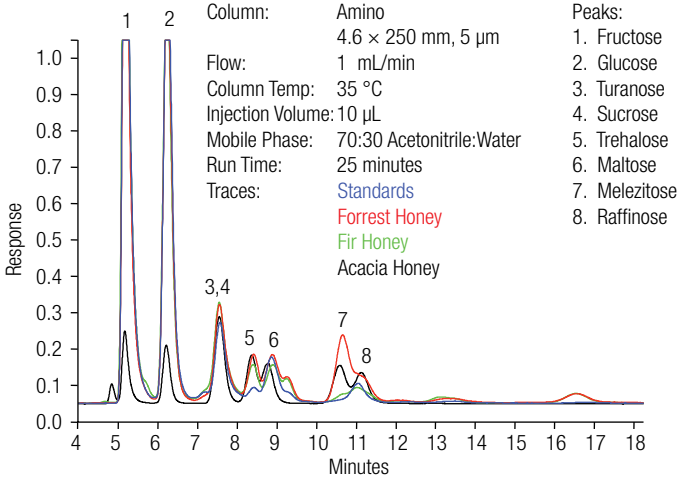

Figure 1-42. Profiling sugars in different honeys using HILIC-Charged Aerosol Detection.

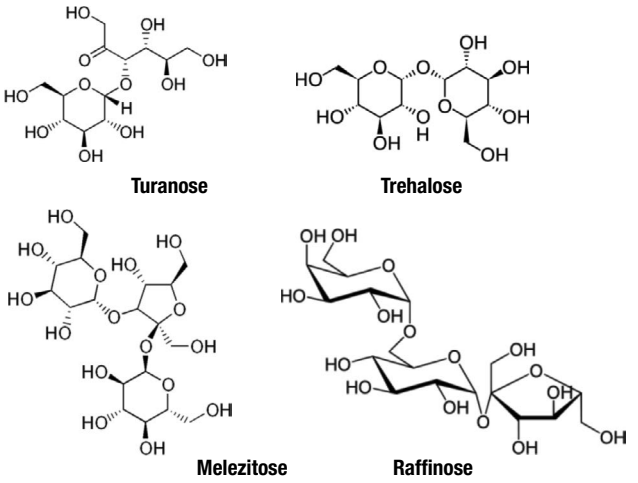

Figure 1-43. Structures of the less common carbohydrates found in honey.

Did You Know?

Not all honey is safe to eat. Honey produced from flowers of oleanders, rhododendrons, mountain laurels, and azaleas may cause honey intoxication (due to grayanotoxin poisoning). Commercial processing, with pooling of honey from numerous sources, is thought to dilute any toxins, rendering contaminated honey safe to consume.

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References

Technical Collateral and Peer Reviewed Journals

Here you'll find a multitude of references using our HPLC, ion chromatography and sample preparation solutions.

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Table of Contents

References

HPLC and UHPLC References

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Peer Reviewed Journals: HPLC and UHPLC Methods

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Carbohydrates

Title	Authors	Publication	Publication Date
Cellotriose and cellotetraose as inducers of the genes encoding cellobiohydrolases in the basidiomycete Phanerochaete chrysosporium	Suzuki, H.; Igarashi, K.; Samejima, M.	*Appl. Environ. Microbiol. 76 (18),* 6164–6170	2010 Sep
1,2-alpha-l-Fucosynthase: A glycosynthase derived from an inverting alpha-glycosidase with an unusual reaction mechanism	Wada, J.; Honda, Y.; Nagae, M.; Kato, R.; Wakatsuki, S.; Katayama, T.; Taniguchi, H.; Kumagai, H.; Kitaoka, M.; Yamamoto, K.	*FEBS Lett. 582 (27),* 3739–3743	2008 Nov 12
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Food, Nutrition, Natural Products, and Supplements

Title	Authors	Publication	Publication Date
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Composition and stability of phytochemicals in five varieties of black soybeans (Glycine max)	Correa, C. R.; Li, L.; Aldini, G.; Carini, M.; Oliver Chen, C. Y.; Chun, H.; Cho, S.; Park, K.; Russell, R. M.; Blumberg, J. B.; Yeum, K.	*Food Chem. 123 (4),* 1176–1184	2010 Dec 15
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alpha-Lipoic acid in dietary supplements: development and comparison of HPLC-CEAD and HPLC-ESI-MS methods	Durrani, A. I.; Schwartz, H.; Schmid, W.; Sontag, G.	*J. Pharm. Biomed. Anal. 45 (4),* 694–699	2007 Nov 30
Comparison between evaporative light scattering detection and charged aerosol detection for the analysis of saikosaponins	Eom, H. Y.; Park, S. Y.; Kim, M. K.; Suh, J. H.; Yeom, H.; Min, J. W.; Kim, U.; Lee, J.; Youm, J. R.; Han, S. B.	*J. Chromatogr., A. 1217 (26),* 4347–4354	2010 Jun 25
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Development and validation of HPLC-DAD-CAD-MS3 method for qualitative and quantitative standardization of polyphenols in *Agrimoniae eupatoriae herba* (Ph. Eur)	Granica, S.; Krupa, K.; Kłębowska, A.; Kiss, A. K.	*J. Pharm. Biomed. Anal. 86,* 112–122	2013 Dec
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Determination of the urinary aglycone metabolites of vitamin K by HPLC with redox-mode electrochemical detection	Harrington, D. J.; Soper, R.; Edwards, C.; Savidge, G. F.; Hodges, S. J.; Shearer, M. J.	*J. Lipid Res. 46 (5),* 1053–1060	2005 May

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A new application of charged aerosol detection in liquid chromatography for the simultaneous determination of polar and less polar ginsenosides in ginseng products	Jia, S.; Li, J.; Yunusova, N.; Park, J. H.; Kwon, S. W.; Lee, J.	*Phytochem. Anal. 24 (4),* 374–380	2013 Jul–Aug
A combination of aspirin and γ-tocopherol is superior to that of aspirin and α-tocopherol in anti-inflammatory action and attenuation of aspirin-induced adverse effects	Jiang, Q.; Moreland, M.; Ames, B. N.; Yin, X.	*J. Nutr. Biochem. 20 (11),* 894–900	2009 Nov
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Analysis of terpene lactones in a Ginkgo leaf extract by high-performance liquid chromatography using charged aerosol detection	Kakigi, Y.; Mochizuki, N.; Icho, T.; Hakamatsuka, T.; Goda, Y.	*Biosci., Biotechnol., Biochem. 74 (3),* 590–594	2010
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Peer Reviewed Journals: HPLC and UHPLC Methods

Food, Nutrition, Natural Products, and Supplements

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Antioxidant-rich food intakes and their association with blood total antioxidant status and vitamin C and E levels in community-dwelling seniors from the Quebec longitudinal study NuAge	Khalil, A.; Gaudreau, P.; Cherki, M.; Wagner, R.; Tessier, D. M.; Fulop, T.; Shatenstein, B.	*Exp. Gerontol. 46 (6),* 475–481	2011 Jun
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Transepithelial transport of microbial metabolites of quercetin in intestinal Caco-2 cell monolayers	Konishi, Y.	*J. Agric. Food Chem. 53 (3),* 601–607	2005 Feb 9
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Pharmacokinetic study of caffeic and rosmarinic acids in rats after oral administration	Konishi, Y.; Hitomi, Y.; Yoshida, M.; Yoshioka, E.	*J. Agric. Food Chem. 53 (12),* 4740–4746	2005 Jun 15
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Effects of various doses of selenite on stinging nettle (*Urtica dioica L.*)	Krystofova, O.; Adam, V.; Babula, P.; Zehnalek, J.; Beklova, M.; Havel, L.; Kizek, R.	*Int. J. Environ. Res. Public Health 7 (10),* 3804–3815	2010 Oct
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Determination of 4-ethylcatechol in wine by high-performance liquid chromatography-coulometric electrochemical array detection	Larcher, R.; Nicolini, G.; Bertoldi, D.; Nardin, T.	*Anal. Chim. Acta 609 (2),* 235–240	2008 Feb 25
Determination of volatile phenols in wine using high-performance liquid chromatography with a coulometric array detector	Larcher, R.; Nicolini, G.; Puecher, C.; Bertoldi, D.; Moser, S.; Favaro, G.	*Anal. Chim. Acta 582 (1),* 55–60	2007 Jan 16

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Food, Nutrition, Natural Products, and Supplements

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Acute, quercetin-induced reductions in blood pressure in hypertensive individuals are not secondary to lower plasma angiotensin-converting enzyme activity or endothelin-1: nitric oxide	Larson, A.; Witman, M. A. H.; Guo, Y.; Ives, S.; Richardson, R. S.; Bruno, R. S.; Jalili, T.; Symons, J. D.	*Nutr. Res. (N. Y., NY, U.S.) 32 (8),* 557–564	2012 Aug
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Reversed-phase high-performance liquid chromatography method with coulometric electrochemical and ultraviolet detection for the quantification of vitamins B(1) (thiamine), B(6) (pyridoxamine, pyridoxal and pyridoxine) and B(12) in animal and plant foods	Lebiedzin´ska, A.; Marszałł, M. L.; Kuta, J.; Szefer, P.	*J. Chromatogr., A 1173 (1–2),* 71–80	2007 Nov 30
An improved method for the determination of green and black tea polyphenols in biomatrices by high-performance liquid chromatography with coulometric array detection	Lee, M. J.; Prabhu, S.; Meng, X.; Li, C.; Yang, C. S.	*Anal. Biochem. 279 (2),* 164–169	2000 Mar 15
Characterisation, extraction efficiency, stability and antioxidant activity of phytonutrients in *Angelica keiskei*	Li, L.; Aldini, G.; Carini, M.; Chen, C. Y. O.; Chun, H.; Cho, S.; Park, K.; Correa, C. R.; Russell, R. M.; Blumberg, J. B.; Yeum, K.	*Food Chem.* 115 (1), 227–232	2009 Jul
Vitamin A equivalence of the β-carotene in β-carotene-biofortified maize porridge consumed by women	Li, S.; Nugroho, A.; Rocheford, T.; White, W. S.	*Am. J. Clin. Nutr. 92 (5),* 1105–1112	2010 Nov
Phase IIa chemoprevention trial of green tea polyphenols in high-risk individuals of liver cancer: modulation of urinary excretion of green tea polyphenols and 8-hydroxydeoxyguanosine	Luo, H.; Tang, L.; Tang, M.; Billam, M.; Huang, T.; Yu, J.; Wei, Z.; Liang, Y.; Wang, K.; Zhang, Z. Q.; Zhang, L.; Wang, J. S.	*Carcinogenesis 27 (2),* 262–268	2006 Feb
Determination of four water-soluble compounds in *Salvia miltiorrhiza Bunge* by high-performance liquid chromatography with a coulometric electrode array system	Ma, L.; Zhang, X.; Guo, H.; Gan, Y.	*J. Chromatogr., B: Anal. Technol. Biomed. Life Sci. 833* (2), 260–263	2006 Apr 3
Effect of green tea powder (*Camellia sinensis L.* cv. Benifuuki) particle size on O-methylated EGCG absorption in rats, The Kakegawa Study	Maeda-Yamamoto, M.; Ema, K.; Tokuda, Y.; Monobe, M.; Tachibana, H.; Sameshima, Y.; Kuriyama, S.	*Cytotechnology 63 (2),* 171–179	2011 Mar
Supplementation of a γ-tocopherol-rich mixture of tocopherols in healthy men protects against vascular endothelial dysfunction induced by postprandial hyperglycemia	Mah, E.; Noh, S. K.; Ballard, K. D.; Park, H. J.; Volek, J. S.; Bruno, R. S.	*J. Nutr. Biochem. 24 (1),* 196–203	2013 Jan

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Food, Nutrition, Natural Products, and Supplements

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Determination of water-soluble vitamins in infant milk and dietary supplement using a liquid chromatography on-line coupled to a corona-charged aerosol detector	Márquez-Sillero, I.; Cárdenas, S.; Valcárcel, M.	*J. Chromatogr., A. 1313C,* 253–258	2013 Oct 25
Sensitive high-performance liquid chromatographic method using coulometric electrode array detection for measurement of phytoestrogens in dried blood spots	Melby, M. K.; Watanabe, S.; Whitten, P. L.; Worthman, C. M.	*J. Chromatogr., B: Anal. Technol. Biomed. Life Sci. 826 (1–2),* 81–90	2005 Nov 5
Phenolic acids from beer are absorbed and extensively metabolized in humans	Nardini, M.; Natella, F.; Scaccini, C.; Ghiselli, A.	*J. Nutr. Biochem. 17 (1),* 14–22	2006 Jan
High-performance liquid chromatography analysis of plant saponins: An update 2005-2010	Negi, J. S.; Singh, P.; Pant, G. J.; Rawat, M. S.	*Pharmacogn. Rev. 5 (10),* 155–158	2011 Jul
Physicochemical effect of pH and antioxidants on mono- and triglutamate forms of 5-methyltetrahydrofolate, and evaluation of vitamin stability in human gastric juice: Implications for folate bioavailability	Ng, X.; Lucock, M.; Veysey, M.	*Food Chem. 106 (1),* 200–210	2008 Jan
Practical preparation of lacto-*N*-biose I, a candidate for the bifidus factor in human milk	Nishimoto, M.; Kitaoka, M.	*Biosci., Biotechnol., Biochem. 71 (8),* 2101-2104	2007 Aug
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Peer Reviewed Journals: HPLC and UHPLC Methods

Food, Nutrition, Natural Products, and Supplements

Title	Authors	Publication	Publication Date
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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Food, Nutrition, Natural Products, and Supplements

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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Food, Nutrition, Natural Products, and Supplements

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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Food, Nutrition, Natural Products, and Supplements

Title	Authors	Publication	Publication Date
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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Lipids

Title	Authors	Publication	Publication Date
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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Lipids

Title	Authors	Publication	Publication Date
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Thermo SCIENTIFIC

Peer Reviewed Journals: HPLC and UHPLC Methods

Lipids

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Determination of intralumenal individual bile acids by HPLC with charged aerosol detection	Vertzoni, M.; Archontaki, H.; Reppas, C.	*J. Lipid Res. 49 (12),* 2690–2695	2008 Dec
Neurolipids and the use of a charged aerosol detector	Waraska, J.; Acworth, I.	*Am. Biotechnol. Lab. 26 (1),* 12–13	2008

Thermo SCIENTIFIC

Technical Collateral: HPLC and UHPLC Methods

Table of Contents

Product Number	Technique	Title
AB 119	UV	Rapid Separation of Paclitaxel and Related Compounds in Paclitaxel Injection
AB 134	MS	LC-MS Analysis of Anthocyanins in Bilberry Extract
AB 139	UV	Separation of Schizandrin, Schizandrin A, and Schizandrin B in a Tablet Sample
AB 153	UV	Save the Flavor – Robust Iso-α-Acids Assaying in Beer within Ten Minutes
AB 155	UV	Monitor the Brewing Process with LC-Transformation of Hop alpha-Acids into Beer Iso-alpha-Acids
AN 109	FLD	Determination of Glyphosate by Cation-Exchange Chromatography with Postcolumn Derivatization
AN 156	UV	The Everlasting Paradigm-Keep Beer Tradition or Prevent Beer from a Skunky Off-Flavor?
AN 196	FLD	Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Edible Oils by Donor-Acceptor Complex Chromatography (DACC)-HPLC with Fluorescent Detection
AN 207	UV	Chromatographic Fingerprinting of *Flos Chrysanthema indici* Using HPLC
AN 213	UV/FLD	Determination of Polycyclic Aromatic Hydrocarbons (PAHs) in Tap Water Using on-Line Solid-Phase Extraction Followed by HPLC with UV and Fluorescence Detections
AN 216	UV	Determination of Water- and Fat-Soluble Vitamins in Functional Waters by HPLC with UV-PDA Detection
AN 224	UV	Determination of Melamine in Milk Powder by Reversed-Phase HPLC with UV Detection
AN 232	UV	Determination of Anthraquinones and Stilbenes in Giant Knotweed Rhizome by HPLC with UV Detection
AN 236	UV	Determination of Iodide and Iodate in Seawater and Iodized Table Salt by HPLC-UV Detection
AN 245	UV	Fast Analysis of Dyes in Foods and Beverages
AN 251	UV	Determination of Water- and Fat-Soluble Vitamins in Nutritional Supplements by HPLC with UV Detection
AN 252	UV	HPLC Assay of Water-Soluble Vitamins, Fat-Soluble Vitamins, and a Preservative in Dry Syrup Multivitamin Formulation
AN 261	UV	Sensitive Determination of Microcystins in Drinking and Environmental Waters
AN 264	UV	Fast Determination of Anthocyanins in Pomegranate Juice
AN 266	FLD	Determination of Sialic Acids Using UHPLC with Fluorescence Detection
AN 272	FLD	Faster Yet Sensitive Determination of N-Methylcarbamates in Rice, Potato, and Corn by HPLC
AN 275	UV	Sensitive Determination of Catechins in Tea by HPLC
AN 287	UV	Two-Dimensional HPLC Combined with On-Line SPE for Determination of Sudan Dyes I–IV in Chili Oil
AN 292	UV	Determination of Aniline and Nitroanilines in Environmental and Drinking Waters by On-Line SPE
AN 293	CAD and UV	Steviol Glycoside Determination by HPLC with Charged Aerosol and UV Detections Using the Acclaim Trinity P1 Column
AN 299	UV	HPLC Analysis of Six Active Components of *Caulis Ionicerae* Using a Phenyl-1 Column
AN 1008	UV	Determination of Nitidine Chloride, Toddalolactone, and Chelerythrine Chloride by HPLC

Thermo SCIENTIFIC

Technical Collateral: HPLC and UHPLC Methods

Product Number	Technique	Title
AN 1020	EC, UV	Chalcinoids and Bitter Acids in Beer by HPLC with UV and ECD
AN 1023	UV	Determination of Sudan Dyes I–IV in Curry Paste
AN 1026	CAD	Fatty Acid Esters at Low Nanogram Levels
AN 1027	CAD	Ginseng
AN 1028	CAD	Ginkgo biloba
AN 1029	CAD	Black Cohosh
AN 1030	CAD	Soy Saponins
AN 1032	CAD	Unsaturated Fatty Acid: Arachidonic, Linoleic, Linolenic and Oleic Acids
AN 1033	CAD	Corn Syrup
AN 1034	CAD	Honey Sugars
AN 1035	CAD	Phenolic Acids
AN 1036	CAD	Water-Soluble Antioxidants: Ascorbic Acid, Glutathione and Uric Acid
AN 1037	CAD	Artificial Sweeteners-Global Method
AN 1039	CAD	Simultaneous Measurement of Glycerides (Mono-, Di- and Triglycerides) and Free Fatty Acids in Palm Oil
AN 1040	CAD	Analysis of Commercially Available Products Containing Stevia
AN 1041	CAD	Phytosterols
AN 1042	UV	Rapid Separation of Anthocyanins in Cranberry and Bilberry Extracts Using a Core-Shell Particle Column
AN 1045	UV	Determination of Phthalates in Drinking Water by UHPLC with UV Detection
AN 1046	UV	Determination of Phenylurea Compounds in Tap Water and Bottled Green Tea
AN 1055	CAD	Determination of Virginiamycin, Erythromycin, and Penicillin in Dried Distillers Grains with Solubles
AN 1063	ECD	Targeted Analyses of Secondary Metabolites in Herbs, Spices, and Beverages Using a Novel Spectro-Electro Array Platform
AN 1064	ECD	Product Authentication and Adulteration Determination Using a Novel Spectro-Electro Array Platform
AN 1067	UV	Determination of Carbendazim in Orange Juice
AN 1069	UV	Two-Dimensional HPLC Determination of Water-Soluble Vitamins in a Nutritional Drink
AN 1070	UV	Determination of Inositol Phosphates in Dried Distillers Grains and Solubles
AN 20583	UV	Determination of Catechins and Phenolic Acids in Red Wine by Solid Phase Extraction and HPLC
AN 20610	UV	Fast Analysis of Coffee Bean Extracts Using a Solid Core HPLC Column
AN 20663	CAD	Comparative Analysis of Cooking Oils Using a Solid Core HPLC Column
AN 20847	CAD	Analysis of a Sports Beverage for Electrolytes and Sugars Using Multi-Mode Chromatography with Charged Aerosol Detection

Thermo SCIENTIFIC

Technical Collateral: HPLC and UHPLC Methods

Product Number	Technique	Title
AN 70158	CAD	Novel Universal Approach for the Measurement of Natural Products in a Variety of Botanicals and Supplements
AN 70277	CAD	Simultaneous Analysis of Glycerides and Fatty Acids in Palm Oil
AU 144	UV	Determination of Hexavalent Chromium in Drinking Water Using Ion Chromatography
AU 170	UV	Fast Determination of Vanillin and its Synthesis Precursor by HPLC
AU 182	CAD	Measuring Lactose in Milk: A Validated Method
AU 184	CAD, UV	Mogroside V Determination by HPLC with Charged Aerosol and UV Detections
CAN 106	UV	Determination of the Punicalagins Found in Pomegranate by High Performance Liquid Chromatography
CAN 111	CAD	Determination of Triterpenes in *Centella asiatica* (Gotu Kola) by HPLC-CAD
CAN 112	CAD	Determination of Ginsenosides in Panax ginseng by HPLC-CAD
CAN 115	FLD	Clean-Up and Analysis of Aflatoxins and Ochratoxin A in Herbs and Spices
LPN 2062	MS	Profiling Analysis of 15 Prominent Naturally Occurring Phenolic Acids by LC-MS
LPN 2069	FLD	Fast and Effective Determination of Aflatoxins in Grains or Food Using Accelerated Solvent Extraction followed by HPLC
LPN 2421	UV	Achieving Maximum Productivity by Combining UHPLC with Advanced Chromatographic Techniques
LPN 2818	CAD	Analysis of Fat-Soluble Vitamins and Antioxidants in Supplements by RP-HPLC
LPN 2870	FLD	Benefits of High-Speed Wavelength Switching in UHPLC Methods Using Fluorescence Detection
LPN 2930	CAD	Determination of the Composition of Natural Products by HPLC with Charged Aerosol Detection
LPN 2923	CAD	Simple and Direct Analysis of Falcarinol and Other Polyacetylenic Oxylipins in Carrots by Reversed-Phase HPLC and Charged Aerosol Detection
LPN 2931	CAD	Quantification of Underivatized Omega-3 and Omega-6 Fatty Acids in Foods by HPLC CAD
LPN 2932	ECD	A Versatile Detector for the Sensitive and Selective Measurement of Numerous Fat-Soluble Vitamins and Antioxidants in Human Plasma and Plant Extracts
LPN 2934	CAD	Sensitive Analysis of Commonly Used Artificial and Natural Sweeteners Including Stevia and Their Impurities and Degradation Products
LPN 2991	CAD	Evaluation of Methods for the Characterization and Quantification of Polysorbates and Impurities Along with Other Surfactants and Emulsifiers Used in the Food and Pharmaceutical Industries
PN 70026	CAD	Carbohydrate Analysis Using PAD, FLD, CAD and MS Detectors
PN 70037	CAD	Sensitive HPLC Method for Triterpenoid Analysis Using Charged Aerosol Detection with Improved Resolution
PN 70055	CAD	Direct Analysis of Surfactants using HPLC with Charged Aerosol Detection
PN 70138	UV	Rapid Determination of Polyphenol Antioxidants in Green Tea and Cranberry Extract Using Core Shell Columns
PN 70538	CAD	Analysis of Silicone Oils by HPLC-CAD
PN 70540	CAD, ECD	Profiling *Hoodia* Extracts by HPLC with CAD, ECD, Principal Component Analysis

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Table of Contents

Ion Chromatography References

Thermo SCIENTIFIC

Technical Collateral: Ion Chromatography Methods

Product Number	Technique	Title
AB 127	IC-PAD	Determination of Carbohydrates in Fruit Juice Using Capillary High-Performance Anion-Exchange Chromatography
AB 135	IC-SC	Determination of Anions and Organic Acids in Brewed Coffee Samples Using Capillary IC
AB 137	IC-SC	Determination of Inorganic and Organic Acids in Apple and Orange Juice Samples Using Capillary IC
AN 25	IC-SC	Determination of Inorganic Ions and Organic Acids in Non-Alcoholic Carbonated Beverages
AN 37	IC-PAD	Determination of Iodide and Iodate in Soy- and Mil-Based Infant Formulas
AN 46	IC-PAD	Ion Chromatography: A Versatile Technique for the Analysis of Beer
AN 54	IC-PAD	Determination of Total and Free Sulfite in Foods and Beverages
AN 67	IC-PAD	Determination of Plant-Derived Neutral Oligo- and Polysaccharides
AN 81	IC-SC	Ion Chromatographic Determination of Oxyhalides and Bromide at Trace Level Concentrations in Drinking Water Using direct Injection
AN 82	IC-PAD	Analysis of Fruit Juice Adulterated with Medium Invert Sugar from Beets
AN 87	IC-PAD	Determination of Sugar Alcohols in Confections and Fruit Juices by High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection
AN 101	IC-SC	Trace Level Determination of Bromate in Ozonated Drinking Water Using Ion Chromatography
AN 112	IC-UV	Determination of Nitrate and Nitrite in Meat Using High-Performance Anion-Exchange Chromatography
AN 121	IC-SC	Analysis of Low Concentrations of Perchlorate in Drinking Water and Ground Water by Ion Chromatography
AN 123	IC-SC	Determination of Inorganic Anions and Organic Acids in Fermentation Broths
AN 133	IC-SC	Determination of Inorganic Anions in Drinking Water by Ion Chromatography
AN 136	IC-SC and IC-UV	Determination of Inorganic Oxyhalide Disinfection Byproduct Anions and Bromide in Drinking Water Using Ion Chromatography with the Addition of a Postcolumn Reagent for Trace Bromate Analysis
AN 140	IC-SC	Fast Analysis of Anions in Drinking Water by Ion Chromatography
AN 143	IC-SC	Determination of Organic Acids in Fruit Juices
AN 149	IC-SC	Determination of Chlorite, Bromate, Bromide, and Chlorate in Drinking Water by Ion Chromatography with an On-Line-Generated Postcolumn Reagent for Sub-µg/L Bromate Analysis
AN 150	IC-PAD	Determination of Amino Acids in Cell Cultures and Fermentation Broths
AN 154	IC-SC	Determination of Inorganic Anions in Environmental Waters Using a Hydroxide-Selective Column
AN 155	IC-PAD	Determination of Trans-Galactooligosaccharides in Foods by AOAC Method 2001.02

Technical Collateral: Ion Chromatography Methods

Product Number	Technique	Title
AN 165	IC-SC	Determination of Benzoate in Liquid Food Products by Reagent-Free Ion Chromatography
AN 167	IC-SC	Determination of Trace Concentrations of Oxyhalides and Bromide in Municipal and Bottled Waters Using a Hydroxide-Selective Column with a Reagent-Free Ion Chromatography System
AN 168	IC-UV	Determination of Trace Concentrations of Disinfection By-Product Anions and Bromide in Drinking Water Using Reagent-Free Ion Chromatography Followed by Postcolumn Addition of Iol-Dianisidine for Trace Bromate Analysis
AN 169	IC-SC	Rapid Determination of Phosphate and Citrate in Carbonated Soft Drinks Using a Reagent-Free Ion Chromatography System
AN 172	IC-SC	Determination of Azide in Aqueous Samples by Ion Chromatography with Suppressed Conductivity Detection
AN 173	IC-PAD	Direct Determination of Cyanide in Drinking Water by Ion Chromatography with Pulsed Amperometric Detection (PAD)
AN 178	IC-SC	Improved Determination of Trace Concentrations of Perchlorate in Drinking Water Using Preconcentration with Two-Dimensional Ion Chromatography and Suppressed Conductivity Detection
AN 182	IC-SC and IC-PAD	Determination of Biogenic Amines in Alcoholic Beverages by Ion Chromatography with Suppressed Conductivity and Integrated Pulsed Amperometric Detections
AN 183	IC-SC and IC-PAD	Determination of Biogenic Amines in Fermented and Non-Fermented Foods Using Ion Chromatography with Suppressed Conductivity and Integrated Pulsed Amperometric Detections
AN 187	IC-SC	Determination of sub-µg/L Bromate in Municipal Waters Using Preconcentration with Two-Dimensional Ion Chromatography and Suppressed Conductivity Detection
AN1 88	IC-PAD	Determination of Glycols and Alcohols in Fermentation Broths Using Ion-Exclusion Chromatography and Pulsed Amperometric Detection
AN 197	IC-PAD	Determination of Glucosamine in Dietary Supplements Using HPAE-PAD
AN 227	ICE-PAD	Determination of Total Cyanide in Municipal Wastewater and Drinking Water Using Ion-Exclusion Chromatography with Pulsed Amperometric Detection (ICE-PAD)
AN 248	IC-PAD	Determination of Lactose in Lactose-Free Milk Products by High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection
AN 253	IC-PAD	HPAE-PAD Determination of Infant Formula Sialic Acids
AN 270	IC-PAD	Determination of Hydroxymethylfurfural in Honey and Biomass
AN 273	IC-SC	Determination of Organic Acids in Fruit Juices and Wines by High-Pressure IC
AN 279	IC-SC	Time Savings and Improved Reproducibility of Nitrate and Nitrite Ion Chromatography Determination in Milk Samples
AN 280	IC-PAD	Carbohydrates in Coffee: AOAC Method 995.13 vs a New Fast Ion Chromatography Method
AN 295	IC-SC	Determination of Phytic Acid in Soybeans and Black Sesame Seeds
AN 1007	IC-SC	Determination of Mono-, Di-, and Triphosphates and Citrate in Shrimp by Ion Chromatography

Thermo SCIENTIFIC

Technical Collateral: Ion Chromatography Methods

Product Number	Technique	Title
AN 1044	IC-SC	Determination of Anions in Dried Distillers Grains with Solubles
AN 1068	IC-SC	Determination of Organic Acids in Fruit Juices and Wines by High-Pressure IC
AU 132	IC-UV	Determination of Nitrite and Nitrate in drinking Water by Ion Chromatography with Direct UV Detection
AU 144	IC-UV	Determination of Hexavalent Chromium in Drinking Water Using Ion Chromatography
AU 148	IC-SC	Determination of Perchlorate in Drinking Water Using Reagent-Free Ion Chromatography
AU 150	IC-PAD	Determination of Plant-Derived Neutral Oligo- and Polysaccharides Using the CarboPac PA200
AU 151	IC-PAD	Determination of Sucralose in Reduced- Carbohydrate Colas using High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection
AU 189	IC-SC	Determination of Choline in Infant Formula and Other Food Samples by IC
LPN 2982	IC-SC	Determination of Inorganic Anions and Organic Acids in Beverages Using a Capillary IC on a Monolith Anion-Exchange Column
PN 70743	IC-SC	Determination of Perchlorate Levels in Food and Soil Samples Using Accelerated Solvent Extraction and Ion Chromatography
TN 20	IC-PAD	Analysis of Carbohydrates by High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection (HPAE-PAD)
TN 126	IC-SC	Determination of Organic Acids in Beer Samples Using a High-Pressure Ion Chromatography System
TN 135	IC-PAD	Determinations of Monosaccharides and Disaccharides in Beverages by Capillary HPAE-PAD

Table of Contents

References

Sample Preparation References

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Thermo SCIENTIFIC

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Thermo SCIENTIFIC

Peer Reviewed Journals: Sample Preparation Methods

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Thermo SCIENTIFIC

Peer Reviewed Journals: Sample Preparation Methods

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Comparison of sample preparation methods, validation of an UPLC-MS/MS procedure for the quantification of tetrodotoxin present in marine gastropods and analysis of pufferfish	Nzoughet, J. K.; Campbell, K.; Barnes, P.; Cooper, K. M.; Chevallier, O. P, Elliott, C. T.	*Food Chem. 15; 136 (3-4),* 1584–9	2013 Feb
Multiresidue analysis of pesticides in vegetables and fruits using two-layered column with graphitized carbon and water absorbent polymer	Obana, H.; Akutsu, K.; Okihashi, M.; Hori, S.	*The Analyst 123,* 711–714	1998
Analysis of 2-alkylcyclobutanones with accelerated solvent extraction to detect irradiated meat and fish	Obana, H.; Furuta, M.; Tanaka, Y.	*J. Agric. Food Chem. 53 (17),* 6603–8	2005 Aug

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Title	Authors	Publication	Publication Date
Determination of organophosphorus pesticides in foods using an accelerated solvent extraction system	Obana, H.; Kikuchi, K.; Okihashi, M.; Hori, S.	*Analyst 122 (3),* 217–20	1997 Mar
Pressurized hot water extraction of berberine, baicalein and glycyrrhizin in medicinal plants	Ong, E. S.; Shea Mei, L.	*Anal. Chim. Acta. 482 (1),* 81–89	2003 Apr
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Rapid determination of pesticide multiresidues in vegetables and fruits by accelerated solvent extraction coupled with online gel permeation chromatography-gas chromatography-mass spectrometry	Ouyang, Y.; Tang, H.; Wu, Y.; Li, G.	*Se Pu. 30(7),* 654–9	2012 Jul
Determination of zearalenone from wheat and corn by pressurized liquid extraction and liquid chromatography-electrospray mass spectrometry	Pallaroni, L.; von Holst, C.	*J. Chromatogr., A. 993,* 39–45	2003
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Stability of phenolic compounds during extraction with superheated solvents	Palma, M.; Piñeiro, Z.; Barroso, C. G.	*J. Chromatogr., A. 6 921 (2),* 169–74	2001 Jul
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Simultaneous determination of 405 pesticide residues in grain by accelerated solvent extraction then gas chromatography-mass spectrometry or liquid chromatography-tandem mass spectrometry	Pang, G.; Liu, Y.; Fan, C.; Zhang, J.; Cao, Y.; Li, X.; Li, Z.; Wu, Y.; Guo, T.	*Anal. Bioanal. Chem. 384,* 1366–1408	2006 Mar
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Simultaneous determination of 13 quinolones from feeds using accelerated solvent extraction and liquid chromatography	Pecorelli, I.; Galarini, R.; Bibi, R.; Floridi, A. I.; Casciarri, E.; Floridi, A.	*Anal. Chim. Acta. 483 (1-2),* 81–89	2003 April
Comparison of soxhlet, ultrasound-assisted and pressurized liquid extraction of terpenes, fatty acids and Vitamin E from *Piper gaudichaudianum* Kunth	Péres, V. F.; Saffi, J.; Melecchi, M. I.; Abad, F. C.; de Assis Jacques, R.; Martinez, M. M.; Oliveira, E. C.; Caramão, E. B.	*J. Chromatogr., A. 1105 (1-2),* 115–8	2006 Feb
Pressurised fluid extraction (PFE) as an alternative general method for the determination of pesticide residues in rape seed	Pihlström, T.; Isaac, G.; Waldebäck, M.; Osterdahl, B. G.; Markides, K. E.	*Analyst 127 (4),* 554–9	2002 Apr
Determination of catechins by means of extraction with pressurized liquids	Piñeiro, Z.; Palma, M.; Barroso C. G.	*J. Chromatogr., A. 13 1026 (1-2),* 19–23.	2004 Feb

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An improved clean-up strategy for simultaneous analysis of polychlorinated diben-zo-p-dioxins (PCDD), polychlorinated dibenzofurans (PCDF), and polychlorinated biphenyls (PCB) in fatty food samples	Pirard, C.; Focant, J. F.; De, P. E.	*Anal. Bioanal. Chem. 372 (2),* 373–81.	2002 Jan
Extraction of polar and hydrophobic pollutants using accelerated solvent extraction (ASE)	Pörschmann, J., Plugge, J.	*Fresen. J. Anal. Chem. 364 (7),* 643–645	1999
Quantification of the total amount of artemisinin in leaf samples by thin layer chromatography	Quennoz, M.; Bastian, C.; Simonnet, X.; Grogg, A. F.	*Chimia (Aarau) 64 (10),* 755–7.	2010
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Influence of altitudinal variation on the content of phenolic compounds in wild populations of *Calluna vulgaris,* Sambucus nigra, and *Vaccinium myrtillus*	Rieger, G.; Müller, M.; Guttenberger, H.; Bucar, F.	*J. Agric. Food Chem. 56 (19),* 9080–6.	2008 Oct
Pressurized liquid extraction of isoflavones from soybeans	Rostagno, M. A.; Palma, M.; Barroso, C. G.	*Anal. Chim. Acta. 522 (2),* 169–177.	2004 Sep
A multi-residue method for the analysis of organophosphorus residues in cooked and polished rice using accelerated solvent extraction and dispersive-solid phase extraction (D-SPE) technique and uncertainty measurement	Sanyal, D.; Rani, A.; Alam, S.	*J. Environ. Sci. Health, B 44 (7),* 706–16.	2009 Sep
Accelerated solvent extraction of lipids for determining the fatty acid composition of biological material	Schäfer, K.	*Anal. Chim. Acta. 358 (1),* 69–77	1998 Jan
HPLC analysis of kaempherol and quercetin derivatives isolated by different extraction techniques from plant matrix	Skalicka-Wozniak, K.; Szypowski, J.; Głowniak, K.	*J. AOAC Int. 94 (1),* 17–21.	Jan-Feb 2011
Statistical evaluation of fatty acid profile and cholesterol content in fish (common carp) lipids obtained by different sample preparation procedures	Spiric, A.; Trbovic, D.; Vranic, D.; Djinovic, J.; Petronijevic, R.; Matekalo-Sverak, V.	*Anal. Chim. Acta. 672 (1-2), 66–71.*	2010 Jul
Application of accelerated solvent extraction in the analysis of organic contaminants, bioactive and nutritional compounds in food and feed	Sun, H.; Ge, X.; Lv, Y.; Wang, A.	*J. Chromatogr., A. 1237,* 1–23.	2012 May
Development of an accelerated solvent extraction, ultrasonic derivatisation LC-MS/MS method for the determination of the marker residues of nitrofurans in freshwater fish	Tao, Y.; Chen, D.; Wei, H.; Yuanhu, P.; Liu, Z.; Huang, L.; Wang, Y.; Xie, S.; Yuan, Z.	*Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 29 (5),* 736–45.	2012
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Determination of 17 macrolide antibiotics and avermectins residues in meat with accelerated solvent extraction by liquid chromatography-tandem mass spectrometry	Tao, Y.; Yu, G.; Chen, D.; Pan, Y.; Liu, Z.; Wei, H.; Peng, D.; Huang, L.; Wang, Y.; Yuan, Z.	*J. Chromatogr. B Analyt. Technol. Biomed. Life Sci. 897,* 64–71.	2012 May
Determination of seven toxaphene congeners in ginseng and milkvetch root by gas chromatography tandem mass spectrometry	Tian, S.; Mao, X.; Miao, S.; Jia, Z.; Wang, K.; Ji, S.	*Se Pu. 30 (1),* 14–20.	2012 Jan

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A consecutive preparation method based upon accelerated solvent extraction and high-speed counter-current chromatography for isolation of aesculin from *Cortex fraxinus*	Tong, X.; Zhou, T, Xiao, X.; Li, G.	*J. Sep. Sci. 35 (24),* 3609–14	2012 Dec
Characterization of anthocyanins and anthocyanidins in purple-fleshed sweetpotatoes by HPLC-DAD/ESI-MS/MS	Truong, V. D.; Deighton, N.; Thompson, R. T.; McFeeters, R. F.; Dean, L. O.; Pecota, K. V.; Yencho, G. C.	*J. Agric. Food Chem. 58 (1),* 404–10	2010 Jan
Fat extraction from acid- and base-hydrolyzed food samples using accelerated solvent extraction	Ullah, S. M.; Murphy, B.; Dorich, B.; Richter, B.; Srinivasan, K.	*J. Agric. Food Chem. 59 (6),* 2169–74.	2011 Mar
Analysis of zearalenone in cereal and swine feed samples using an automated flow-through immunosensor	Urraca, J. L.; Benito-Peña, E.; Pérez-Conde, C.; Moreno-Bondi, M. C.; Pestka, J. J.	*J. Agric. Food Chem. 53 (9),* 3338–3344	2005
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Subcritical water extraction of alkaloids in *Sophora flavescens* Ait. and determination by capillary electrophoresis with field-amplified sample stacking	Wang, H.; Lu, Y.; Chen, J.; Li, J.; Liu, S.	*J. Pharm. Biomed .Anal. 58,* 146–51.	2012 Jan
Evaluation of Soxhlet extraction, accelerated solvent extraction and microwave-assisted extraction for the determination of polychlorinated biphenyls and polybrominated diphenyl ethers in soil and fish samples	Wang, P.; Zhang, Q.; Wang, Y.; Wang, T.; Li X.; Ding, L.; Jiang, G.	*Anal. Chim. Acta. 663 (1),* 43–8.	2010 Mar
Determination of ten pesticides of pyrazoles and pyrroles in tea by accelerated solvent extraction coupled with gas chromatography-tandem mass spectrometry	Xu, D.; Lu, S.; Chen, D.; Lan, J.; Zhang, Z.; Yang, F.; Zhou, Y.	*Se Pu.; 31 (3),* 218–22.	2013 Mar
Online cleanup of accelerated solvent extractions for determination of adenosine 5'-triphosphate (ATP), adenosine 5'-diphosphate (ADP), and adenosine 5'-monophosphate (AMP) in royal jelly using high-performance liquid chromatography	Xue, X.; Wang, F.; Zhou, J.; Chen, F.; Li, Y.; Zhao, J.	*J. Agric. Food Chem. 57 (11),* 4500–5.	2009 Jun
Identification and quantitation of eleven sesquiterpenes in three species of *Curcuma* rhizomes by pressurized liquid extraction and gas chromatography–mass spectrometry	Yang, F. Q.; Li ,S.; Chen, Y.; Lao, S. C.; Wang, YT.; Dong, T. T. X.; Tsim, K. W. K.	*J. Pharm. Biomed. Anal. 39 (3/4),* 552–558	2005 Sep
Dispersive solid-phase extraction cleanup combined with accelerated solvent extraction for the determination of carbamate pesticide residues in *Radix glycyrrhizae* samples by UPLC-MS-MS	Yang, R. Z.; Wang, J. H.; Wang, M. L.; Zhang, R.; Lu, X. Y.; Liu, W. H.	*J. Chromatogr. Sci. 49 (9),* 702–8.	2011 Oct
Simultaneous determination of amitraz and its metabolite residue in food animal tissues by gas chromatography-electron capture detector and gas chromatography-mass spectrometry with accelerated solvent extraction	Yu, H.; Tao, Y.; Le, T.; Chen, D.; Ishsan, A.; Liu, Y, Wang, Y.; Yuan, Z.	*J. Chromatogr. B Analyt. Technol. Biomed. Life Sci. 878 (21),* 1746–52.	2010 Jul
Simultaneous determination of fluoroquinolones in foods of animal origin by a high performance liquid chromatography and a liquid chromatography tandem mass spectrometry with accelerated solvent extraction	Yu, H.; Tao, Y.; Chen, D.; Pan, Y.; Liu, Z.; Wang, Y.; Huang, L.; Dai, M.; Peng, D.; Wang, X.; Yuan, Z.	*J. Chromatogr. B Analyt. Technol. Biomed. Life Sci. 885-886,* 150–9.	2012 Feb

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Response surface modeling and optimization of accelerated solvent extraction of four lignans from *fructus schisandrae*	Zhao, L. C.; He, Y, Deng.; X, Yang, G. L.; Li, W.; Liang, J.; Tang, Q. L.	*Molecules. 17 (4),* 3618–29	2012 Mar
Determination of acetanilide herbicides in cereal crops using accelerated solvent extraction, solid-phase extraction and gas chromatography-electron capture detector	Zhang, Y.; Yang, J.; Shi, R.; Su, Q.; Yao, L.; Li, P.	*J. Sep. Sci. 34 (14),* 1675–82	2011 Jul
Application of accelerated solvent extraction coupled with high-performance counter-current chromatography to extraction and online isolation of chemical constituents from *Hypericum perforatum* L	Zhang, Y.; Liu, C.; Yu, M.; Zhang, Z.; Qi, Y.; Wang, J.; Wu, G.; Li, S.; Yu, J.; Hu, Y.	*J. Chromatogr., A. 1218 (20),* 2827–34	2011 May
Analysis of volatile components in Qingshanlvshui tea using solid-phase microextraction/accelerated solvent extraction-gas chromatography-mass spectrometry	Zhan, J.; Lu, S.; Meng, Z.; Xiang, N.; Cao, Q.; Miao, M.	*Se Pu. 26 (3),* 301–5.	2008 May

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AN 335	HPLC-UV	Accelerated Solvent Extraction (ASE) of Active Ingredients from Natural Products
AN 356	IC-conductivity	Determination of Perchlorate in Vegetation Samples Using Accelerated Solvent Extraction and Ion Chromatography
AN 357	HPLC	Extraction of Phenolic Acids from Plant Tissue Using Accelerated Solvent Extraction (ASE)
AN 363	HPLC	Extraction of Herbal Marker Compounds Using Accelerated Solvent Extraction Compared to Traditional Pharmacopoeia Protocols

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