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Ion Chromatography

Beverage Analysis Applications Summary Notebook

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Introduction

The global beverage industry is growing with new product introductions including vitamin fortified water, energy drinks, anti-aging water, and herbal nutritional supplements. With this growth comes additional analytical challenges. There is also the continuing need to analyze classic favorites such as sodas, fruit juices, milk drinks, alcoholic beverages, and bottled water. To ensure consistent quality, the composition of beverages should be monitored throughout production. Adulteration of starting ingredients can result in incorrect product labeling, which can become a safety and/or regulatory issue. Contamination at any stage of the process can also compromise product quality.

Adulteration

In an attempt to profit from substitute a lower cost ingredient for a higher cost one, adulteration can occur. For example, apple juice can be substituted for cranberry juice, which can be readily detected by the organic acid or carbohydrate profile.

Quality

Beverage quality can be monitored throughout the production process, from the raw ingredients through to the final product. For example, the appearance of elevated levels of the organic acids lactate and acetate in orange juice are early indicators of spoilage making this an undesirable starting material for orange juice based beverages.

Safety/Regulatory Compliance

The global nature of our food supply chain has raised concerns about food safety. Products are grown and processed in a multitude of locations under a variety of regulatory frameworks. These products are kept in various storage conditions which can experience temperature fluctuations that may reduce shelf life, and are handled by many people. Additionally, the authenticity of partially processed beverage stocks may be more frequently called into question due to the challenge of closely monitoring this process if it occurs in a remote location.

Regulatory agencies have been established to ensure foods are safe, wholesome, and are properly labeled. These include the European Union Parliament, UK Food Safety Standards Agency, China Food and Drug Administration, Food Standards Australia New Zealand, and the U.S. Food and Drug Administration (FDA).

Labels inform consumers about the composition of a beverage so they can make prudent decisions about their diet and avoid the presence of unwanted ingredients, such as allergens to which they may have an adverse reaction. Labeling requirements vary considerably by country, but will typically contain the amount of calories, protein, fat, and carbohydrates. In the U.S., labeling is governed by the Nutritional Labeling and Education Act (NLEA) and requires that labels contain specific nutrient content and health messages. The European Commission created Directive 2000/13/EC, that outlines rules for the labeling, presentation, and advertising of foodstuffs. In China, national nutritional labeling laws were implemented in 2013 to regulate the food industry and encourage healthier choices by consumers and require the validation of nutritional claims and functions.

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Beverage Analysis

Beverages can vary widely in their content, from something as basic as water, for which the level of anions and cations can determine its safety and taste, to the complexity of an alcoholic beverage produced by fermentation, in which the concentration of organic acids or carbohydrates can be indicators of quality.

Anions, Cations, and Organic Acids

The contamination limits of small inorganic ions such as chloride and bromide are typically specified in regulations, while others, such as sulfate, have limits that relate to their impact on the palatability of beverages. The organic acid profile of beverages can be an indicator of beverage quality and can be used to identify the presence of adulteration of one juice with a cheaper one. Ion chromatography with suppressed conductivity detection is routinely used to determine these small, charged molecules.

Carbohydrates

Carbohydrates, the primary nutrient in beverages, are difficult to analyze using common chromatography and detection methods as they are very polar compounds, exhibit similar structural characteristics, and lack a suitable chromophore. High-performance anion-exchange chromatography with Pulsed Amperometric Detection (HPAE-PAD) is widely used for determination of carbohydrates. HPAE chromatography takes advantage of the weakly acidic nature of carbohydrates for highly selective separations at high pH using strong anion exchange stationary phases.

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Bottled Water

Bottled water comes from multiple sources including municipalities, wells, natural springs, and surface waters. These waters can vary greatly in ion content and the methods used for sterilization, which can influence their safety and has prompted the creation of strict regulations to assure that levels of ions are below defined limits. Several regulatory approved methods have been developed for the determination of anions using both one- and two-dimensional ion chromatography.

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Applications

- Oxyhalides and Bromide in Municipal and Bottled Waters
- Chlorite, Bromate, and Chlorate in Bottled Natural Mineral Waters
- Bromate in Drinking and Mineral Waters
- Determination of Bromate by ISO Method 11206

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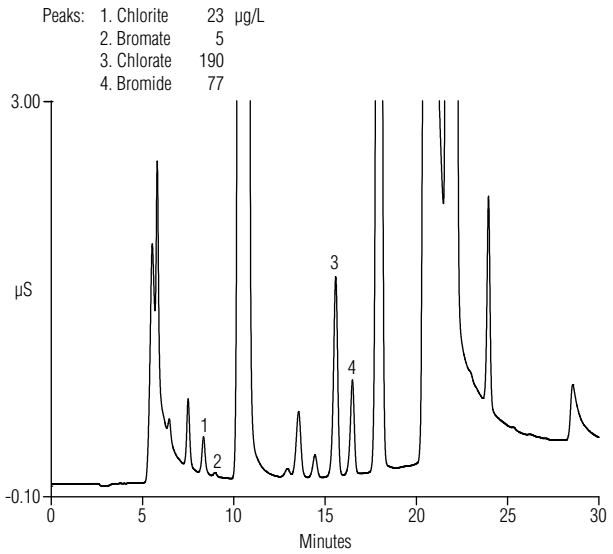
Oxyhalides and Bromide in Municipal and Bottled Waters

All drinking water municipalities share the same goal of providing their communities with a reliable source of safe drinking water. To achieve this goal, most water systems must treat their water. The type of treatment used varies depending on the size, source, and water quality. Disinfection protects public water systems from potentially dangerous microbes. The most common chemical disinfectants are chlorine, chlorine dioxide, chloramine, and ozone. These chemical disinfectants can react with natural organic and inorganic matter in the source water to produce disinfection byproducts (DBPs) that are potentially harmful to humans. For example, chlorination of drinking water can produce trihalomethanes, haloacetic acids, and chlorate.

IC with a hydroxide-selective Thermo Scientific™ Dionex™ IonPac™ AS19 column and an electrolytic eluent generator is an improved approach for determining trace concentrations of DBP anions and bromide in municipal and bottled water samples. The high-capacity Dionex IonPac AS19 column can be used with large-volume injections to detect low-ppb concentrations of bromate, a potential human carcinogen, in many municipal and bottled waters. In addition, electrolytic generation of an ultrapure potassium hydroxide eluent, combined with the Dionex IonPac AS19 column, improves linearity, MDLs, precision, and resolution between bromate and chloride compared to the Dionex IonPac AS9-HC column described in U.S. EPA Method 300.1.

Conditions	
Columns:	Dionex IonPac AS19 Analytical, 4 × 250 mm Dionex IonPac AG19 Guard, 4 × 50 mm
Eluent:	10 mM KOH from 0 to 10 min, 10–45 mM from 10 to 25 min*
Eluent Source:	Thermo Scientific Dionex ICS-2000 EG system with Dionex CR-ATC column
Flow Rate:	1.0 mL/min
Temperature:	30 °C
Injection:	500 µL
Detection:	Suppressed conductivity, Dionex ASRS ULTRA II Suppressor , 4 mm AutoSuppression, recycle mode, 130 mA current
Background Conductance:	<1 µS
System Backpressure:	~2200 psi
Run Time:	30 min

*Method returns to 10 mM KOH for 3 min prior to injection.



Determination of DBP anions and bromide spiked in drinking water A using a 500 µL injection volume.

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Download Application Note 167: 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

Chlorite, Bromate, and Chlorate in Bottled Natural Mineral Waters

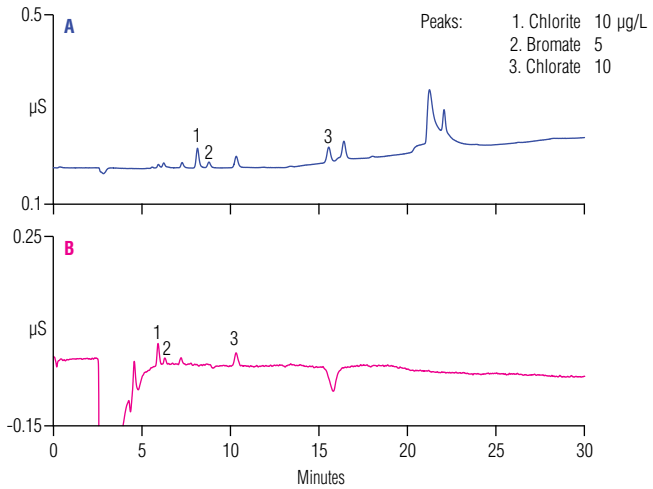
The bottled water industry markets to health conscious consumers as an alternative not only to tap water, but also to carbonated soft drinks and juice drinks. Regardless of whether the water is delivered from a local municipality or is prepackaged in a bottle, the consumption of safe and reliable drinking water is essential to maintain a healthy lifestyle.

Bottled water must be disinfected to remove pathogenic microorganisms and ensure it is safe for human consumption. Water companies prefer ozone as a disinfectant because it is one of the most effective treatments available, it does not leave a taste, and there is no residual disinfectant in the bottled water. Some bottlers, however, use ultraviolet light or chlorine dioxide as alternative treatment methods. Reactions between disinfectants and natural organic and inorganic matter in the source water can result in the production of undesirable disinfection byproducts (DBPs), such as chlorite, bromate, and trihalomethanes, that are potentially harmful to humans.

In this application note, the Dionex IonPac AS19 column using an electrolytically generated hydroxide eluent was compared to the Dionex IonPac AS23 column using an electrolytically generated carbonate/bicarbonate eluent for the determination of trace concentrations of DBP anions in natural mineral waters. The improved sensitivity using a hydroxide eluent allowed the detection of lower concentrations of bromate, a potential human carcinogen, in drinking waters.

Conditions	
Columns:	(A) Dionex IonPac AS19 Analytical, 4 × 250 mm Dionex IonPac AG19 Guard, 4 × 50 mm (B) Dionex IonPac AS23 Analytical, 4 × 250 mm Dionex IonPac AG23 Guard, 4 × 50 mm
Eluent:	(A) 10 mM KOH from 0–10 min, 10–45 mM from 10–25 min, 45 mM from 25–30 min* (B) 4.5 mM K_2CO_3/0.8 mM $KHCO_3$
Eluent Source:	(A) Dionex EGC II KOH cartridge with Dionex CR-ATC column (B) Dionex EGC II K_2CO_3 with Dionex EPM modifier
Flow Rate:	1.0 mL/min
Temperature:	30 °C
Injection:	250 µL
Detection:	(A) Suppressed conductivity, Dionex ASRS ULTRA II suppressor, 4 mm auto-suppression, recycle mode, 130 mA current (B) Suppressed conductivity, Dionex ASRS ULTRA II, suppressor, 4 mm, auto-suppression, external water mode, 25 mA current
CRD:	(A) 4 mm format
Background Conductance:	(A) <1 µS (B) 18–20 µS
System Backpressure:	~2200 psi
Run Time:	30 min

*Method returns to 10 mM KOH for 3 min prior to injection.



Separation of disinfection byproducts using A) the Dionex IonPac AS19 colum and B) the Dionex IonPac AS23 column.

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Download Application Note 184: Determination of Trace Concentrations of Chlorite, Bromate, and Chlorate in Bottled Natural Mineral Waters

Bromate in Drinking and Mineral Waters

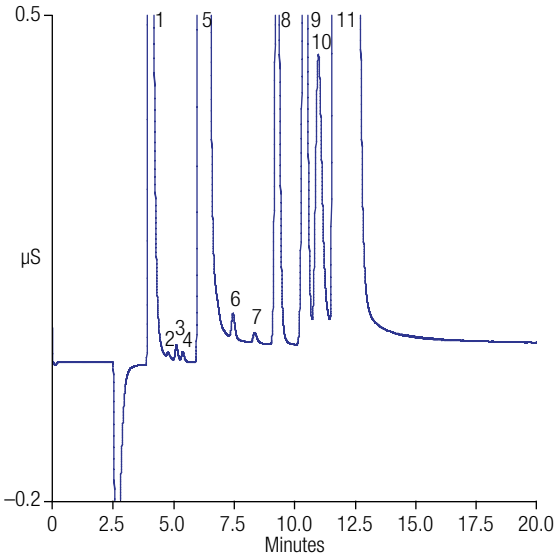
Ozone is a powerful drinking water disinfectant that is effective in treating chlorine resistant organisms, such as Cryptosporidia. For bottled water, ozonation is generally preferred over other available disinfection treatment methods because it does not leave a taste or residual disinfectant, due to the short lifetime of ozone. It also improves the quality of finished drinking water by reducing filtered water turbidity and decreasing the formation of many halogenated disinfection byproducts. However, ozonation of drinking water containing bromide can result in the formation of the disinfection byproduct bromate, a potential human carcinogen even at low µg/L concentrations. Major regulatory bodies worldwide (e.g., U.S. EPA and the European Commission) have set a maximum allowable bromate concentration in drinking water of 10 µg/L. In Europe, the limit was lowered to 3 µg/L for bottled natural mineral and spring waters disinfected by ozonation.

In this application update, bromate was determined in a mineral water sample using the Dionex IonPac AS19 column and isocratic elution. The results of using two sources of eluent, manually prepared hydroxide and hydroxide eluent prepared by an eluent generator, were compared. The results of the MDL, calibration, sample analysis, and percent recovery were used to compare the two eluent sources. The RFIC results were better, but the manually prepared eluents could also determine low µg/L (<10) levels of bromate in mineral and drinking waters.

Conditions	
Column:	Dionex IonPac AS19 Analytical, 4 × 250 mm Dionex IonPac AG19 Guard, 4 × 50 mm
Eluent:	20 mM KOH (RFIC systems), 20 mM NaOH
Eluent Source:	Dionex EluGen II EGC-KOH (for RFIC systems)
Temperature:	25 °C
Flow Rate:	1.0 mL/min
Inj. Volume:	200 µL
Detection:	Thermo Scientific Dionex ASRS ULTRA II suppressor, 4 mm, recycle mode
Suppressor Current:	60 mA
Background:	0.9–1.1 µS (RFIC system), 1.5–2.5 µS (prepared eluent)

Peaks:

1.	Fluoride	0.5 mg/L	6.	Nitrite	0.005
2.	Unknown	n.a.	7.	Chlorate	0.005
3.	Chlorite	0.005	8.	Bromide	0.25
4.	Bromate	0.005	9.	Nitrate	0.25
5.	Chloride	25.0	10.	Carbonate	n.a.
			11.	Sulfate	25.0

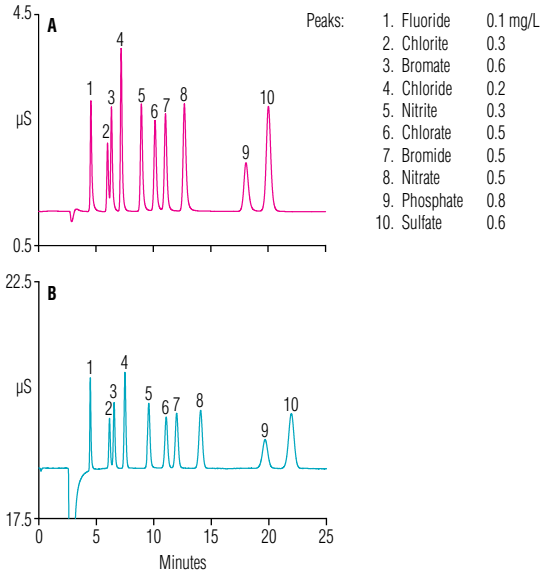


Separation of a mixed anion standard containing 5 µg/L of chlorite, bromate, and chlorate.

Download Application Update 154: Determination of Bromate in Drinking and Mineral Water by Isocratic Ion Chromatography with a Hydroxide Eluent

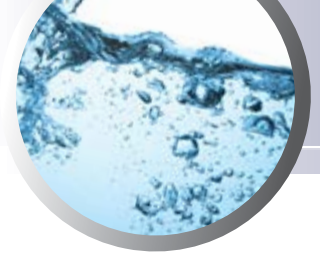
Bromate in Drinking and Mineral Waters

This application note shows that using the Thermo Scientific Dionex CRD 300 Carbonate Removal Device with the Thermo Scientific™ Dionex™ IonPac™ AS23 column, bromate can be determined in bottled mineral water at concentrations < 5 µg/L



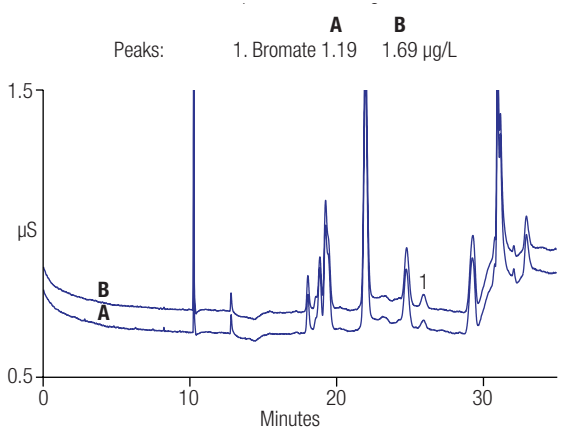
Chromatography of a bottled mineral water sample spked with chlorite, bromate, and chlorate (10 µg/L each) A) with a Dionex CRD 300 Carbonate Removal Device, and B) without a Dionex CRD 300 device.

Conditions	
Condition A (Eluent Generation and Dionex 300 device)	
Column:	Dionex IonPac AS23, 4 × 250 mm Dionex IonPac AG23, 4 × 50 mm
Eluent:	Thermo Scientific Dionex EGC II K_2CO_3 cartridge Thermo Scientific Dionex EPM Modifier 4.5 mM K_2CO_3/0.8 mM $KHCO_3$
Flow Rate:	1.0 mL/min
Inj. Volume:	250 µL
Temperature:	30 °C
Suppressor:	Suppressed conductivity, Thermo Scientific™ Dionex™ ASRS™ 300 Anion Self-Regenerating Suppressor, 4 mm external water mode, 25 mA Dionex CRD 300 device, 4 mm, vacuum mode
Background:	< 1.5 µS
Noise:	~ 0.3 nS
Back Pressure:	~2200 psi
Condition B (Manual Eluent Preparation and no Dionex CRD 300 device)	
Column:	Dionex IonPac AS23, 4 × 250 mm Dionex IonPac AG23, 4 × 50 mm
Eluent:	4.5 mM Na_2CO_3/0.8 mM $NaHCO_3$
Flow Rate:	1.0 mL/min
Inj. Volume:	250 µL
Column Temp:	30 °C
Suppressor:	Suppressed conductivity, Dionex ASRS 300 suppressor, 4 mm external water mode, 25 mA
Background:	17-19 µS
Noise:	~ 3.0 nS
Back Pressure:	~1800 psi



Bromate in Drinking and Mineral Waters

This application note describes a 2-D IC system for the determination of ≥0.5 µg/L bromate in municipal and natural mineral waters. The method provides an improvement to exisiting EPA methods for bromate by providing lower detection limits and improved recoveries of bromate in high-ionic-strength matrices.



Chromatogram of (A) drinking water B and (B) drinking water B fortified with 0.5 µg/L bromate.

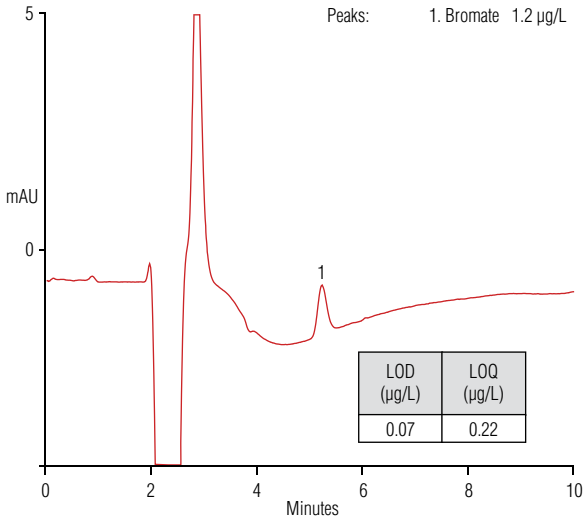
Second Dimension Conditions	
Columns:	Dionex IonPac AG24 Guard, 2 × 50 mm Dionex IonPac AS24 Analytical, 2 × 250 mm
Eluent:	10 mM potassium hydroxide 0–24 min, step to 65 mM at 24 min, 65 mM 24–35 minb
Eluent Source:	Dionex EGC II KOH with Dionex CR-ATC
Flow Rate:	0.25 mL/min
Temperature:	30 °C (lower compartment) 30 °C (upper compartment)
Cut Volume:	2 mL (on the concentrator column)
Concentrator:	Thermo Scientific Dionex IonPac TAC-ULP1, 5 × 23 mm
Detection:	Suppressed conductivity, Dionex ASRS ULTRA II suppressor, 2 mm, auto-suppression, external water mode (flow rate: 1–3 mL/min) Current setting: 41 mA
System Backpressure:	~2400 psi
Expected Background Conductance:	<0.8 µS
Noise:	~2–3 nS/min peak-to-peak
Run Time:	35 min

Determination of Bromate by ISO Method 11206

Bromate is recognized as a potential human carcinogen, which has led to the regulation of its concentration in drinking and bottled waters. Major regulatory bodies worldwide (e.g., U.S. EPA and the European Commission) have set a maximum allowable bromate concentration in drinking water of 10 µg/L. In Europe, the limit was reduced to 3 µg/L for bottled natural mineral and spring waters disinfected by ozonation.

In this technical note, an alternate strategy for a trace analysis of bromate by IC is demonstrated. Bromate is separated using a latex-based anion exchanger and a methanesulfonic acid eluent, followed by a simplified postcolumn reaction to form triiodide. This is subsequently detected by its UV-absorption. Because the reaction takes place at lower pH than other methods, no heating of the reaction coil is needed. These conditions prevent interference from chlorite, which is known to interfere in other bromate determination methods.

Analytical Conditions	
Column:	Thermo Scientific™ Dionex™ CarboPac™ PA1, 4 × 250 mm
Eluent:	200 mM Methanesulfonic acid
Flow Rate:	1.0 mL/min
System Pressure:	1700 psi (11.72 MPa)
Detection:	UV at 352 nm
Injection Volume:	500 µL
Temperature:	30 °C
Sample Preparation:	None
Postcolumn Reagent (PCR):	
PCR:	0.27 M potassium iodide containing 0.05 mM of ammonium heptamolybdate tetrahydrate
Flow Rate:	0.3 mL/min
System Pressure:	1150 psi (7.93 MPa)
Reaction Coil:	375 µL



This chromatogram of a drinking water sample shows a bromate peak with a concentration of 1.2 µ/L. The trace ends at 10 min, although the run time is extended to 18 min due to a later-eluting component.

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Fruit Juice

Fruit juices vary considerably in their nutritional value and cost. With the increase in international sourcing and the temptation of economic adulteration, the need to ensure authenticity is even more important. Fast and reproducible methods have been developed to verify the identity and monitor the quality of juices by using IC that combines Dionex IonPac columns with conductivity detection and Dionex CarboPac columns with PAD.

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- Organic Acids in Fruit Juices
- Organic Acids in Cranberry and Bilberry Extracts
- Organic Acids in Orange Juice
- Inorganic and Organic Acids in Apple and Orange Juice
- Total Inorganic Arsenic in Fruit Juice
- Cations in Fruit Juice
- Carbohydrates in Fruit Juice
- Fruit Juice Adulterated with Medium Invert Sugar
- Sugar Alcohols in Confections and Fruit Juice

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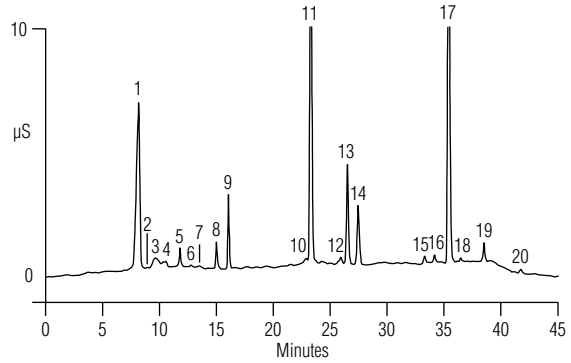
Organic Acids in Fruit Juices

Organic acids are important in characterizing the flavor of fruit juices. Their presence and concentration determine tartness and other flavor attributes. In some cases, it is necessary to determine organic acids to assess whether an expensive juice has been illegally adulterated with a cheaper juice. Because organic acid profiles are distinct to each type of fruit juice, evidence of tampering can be evaluated by comparing the known juice fingerprint to that of the suspected adulterated juice. Organic acid profiles can also determine juice freshness or spoilage.

The method described in this application note can be used to determine organic acids in fruit juices. This method uses eluent generation to generate high-purity, carbonate-free eluents to suppress baseline drift and therefore improve retention time and integration reproducibility. The Dionex IonPac AS11-HC column is the ideal column for this method because its high capacity improves separation of a wide range of organic acids.

Conditions	
Columns:	Dionex IonPac AS11-HC Analytical, 4 mm Dionex IonPac AG11-HC Guard, 4 mm
Eluent:	Potassium hydroxide gradient: 1 mM from 0–8 min 1 mM to 30 mM, 8–28 min 30 mM to 60 mM, 28–38 min Methanol: 10%, 0–38 min
Eluent Source:	Dionex EG50 generator
Flow Rate:	1.5 mL/min
Temperature:	30 °C
Detection System:	Suppressed conductivity, Dionex ASRS ULTRA suppressor, 4 mm, AutoSuppression, external water mode (10 mL/min)
Backpressure:	2900 psi
Background Conductance:	1–4 µS
Degas Setting:	30 s every 2 min
Injection Volume:	10 µL

Peaks:						
	1. Quinate	210	mg/L	11. Succinate	257
	2. Fluoride	<0.1		12. Unknown	-
	3. Lactate/Acetate	10		13. Sulfate	10.3
	4. Glycolate	2.6		14. Oxalate	14.8
	5. Formate	3.7		15. Phosphate	1.8
	6. Pyruvate	2.1		16. Unknown	-
	7. Unknown	-		17. Citrate	163
	8. Galacturonate	16.9		18. Isocitrate	1.0
	9. Chloride	2.3		19. *Trans*-aconitate	2.7
	10. Nitrate	<0.1		20. Unknown	-



Determination of anions and organic acids in cranberry juice cocktail.

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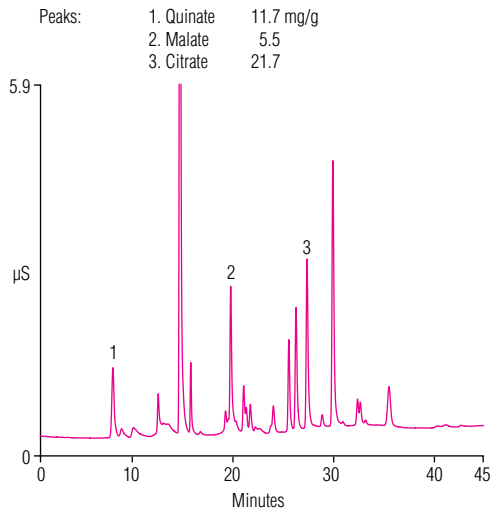
Download Application Note 143: Determination of Organic Acids in Fruit Juices

Organic Acids in Cranberry and Bilberry Extracts

The primary mission of the Office of Dietary Supplements (ODS) at the National Institutes of Health (NIH) is to promote the quality, safety, and efficacy of dietary supplements. To accomplish this mission, authentic reference materials that closely match the matrix components of the dietary supplements are needed. Vaccinium (e.g., cranberries, blueberries, and bilberries) Standard Reference Materials (SRMs) have been developed at the National Institute of Standards and Technologies (NIST) in collaboration with the NIH-ODS to evaluate these types of dietary supplements. These SRMs have certified values for organic acids to aid dietary supplement and juice manufacturers in their analytical method development and QA/QC operations.

This application brief demonstrates the determination of quinic, malic, and citric acids in cranberry and bilberry extracts using a Dionex IonPac AS11-HC column with suppressed conductivity detection.

Conditions	
Column:	Dionex IonPac AG11-HC, Dionex IonPac AS11-HC, 2 mm
Eluent:	1 mM KOH from -8 to 8 min, 1 to 30 mM from 8 to 20 min, 30 to 60 mM from 20 to 30 min, 60 mM from 30 to 45 min Eluent
Eluent Source:	Dionex EGC II KOH cartridge with Dionex CR-ATC Column
Flow Rate:	0.38 mL/min
Temperature:	30 °C
Inj. Volume:	5 µL
Detection:	Suppressed conductivity, Dionex ASRS 300 suppressor 2 mm, recycle mode, 57 mA
Sample Prep.:	0.1 g cranberry extract/160 mL DI water (centrifugation at 25 °C for 15 min for each 40 mL aliquot)



Determination of quinic, malic, and citric acids in cranberry extract.

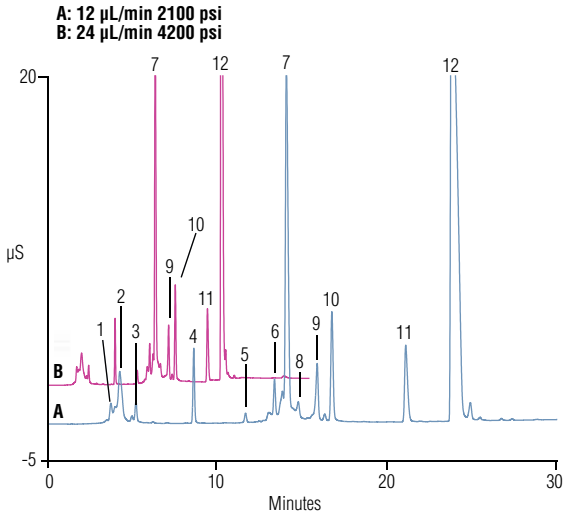
Organic Acids in Orange Juice

Determinations of organic acid profiles in fruit juices are used in the beverage industry to characterize flavor, identifiy spoilage and potential sources of adulteration, and to meet labeling requirements for food products. High-Pressure capillary RFIC systems are the latest advancement in ion chromatography.

This technical note demonstrates how using higher flow rates combined with a high resolution column and a capillary IC system capable of high system pressures can provide comparable separations with 50% shorter run times, therefore increasing sample throughput and saving money and labor.

Peaks:

Quinate	2.0 mg/L	8. Maleate	0.1 mg/L
Lactate	3.2	9. Sulfate	2.0
Formate	0.7	10. Oxalate	4.6
Chloride	1.0	11. Phosphate	7.5
Nitrate	--	12. Citrate	125
Glutarate	--		
Malate	25		



Fast separations or organic acids in a diluted orange juice sample using high-pressure capillary IC.

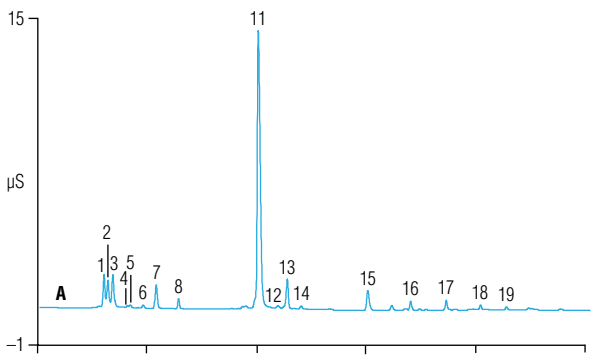
Conditions	
Columns:	Dionex IonSwift MAX 100 guard column, MAX 100, 0.25 × 250 mm
Eluent Source:	Dionex EGC KOH capillary cartridge with Dionex CR-ATC column (capillary)
Gradient:	A: 0.1 mM KOH from -10 to 0.1 min, 0.1–2 mM from 0.1 to 5 min, 2–25 mM from 5 to 20 min, 25–65 mM from 20 to 30 min, 65 mM from 30 to 45.1 min B: Same gradient adjusted for flow rate
Flow Rate:	A: 0.012 mL/min B: 0.024 mL/min
Dionex IC Cube Temp.:	30 °C*
Compartment Temp.:	15 °C
Detection:	Suppressed conductivity, Dionex ACES 300, suppressor Thermo Scientific Dionex CRD 200 Carbonate Removal Device (Capillary), recycle mode, A: 8 mA B: 18 mA
Background Conductance:	< 1.0 µS-cm conductance
Noise:	< 1.0 nS
System backpressure:	A: ~ 2500 psi B: < 4500 psi

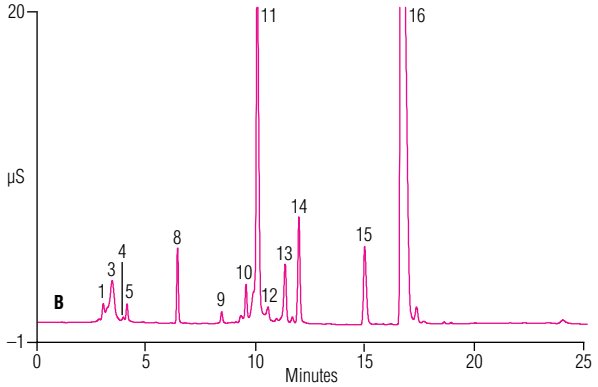
Inorganic and Organic Acids in Apple and Orange Juice

Determinations of organic acids in fruit juices are used by the beverage industry for flavor characterization, identification of spoilage, identification of adulteration by a less costly juice, and product labeling. The concentrations, types, and ratios of organic acids are largely responsible for flavor, tartness, and acidity; therefore, these organic acid analyses are important for delivering a consistent and fresh juice product. Additionally, two common organic acids, acetate and lactate, are caused by biological activity and are, therefore, a good indicator of an old juice that may be spoiled and not fit for consumption.

In this application brief, inorganic anions and organic acids in diluted filtered apple and orange juice samples were determined on a Thermo Scientific™ Dionex™ IonSwift™ MAX-100 Anion-Exchange Column using electrolytically generated hydroxide gradient from 0.1–65 mM KOH over 25 min at 15 µL/min. The analytes were detected by suppressed conductivity using the Thermo Scientific™ Dionex™ ACES™ 300 Anion Capillary Electrolytic Suppressor designed for capillary IC. All analyte peaks eluted within 25 min, demonstrating the column's speed. The analyte peaks were also extremely narrow, which is typical of separations using the Dionex IonSwift MAX-100 column.

Conditions	
Columns:	Dionex IonSwift MAX-100 guard, Dionex MAX-100, capillary, 0.25 mm
Eluent Source:	Dionex EGC-KOH capillary cartridge
Gradient:	0.1 mM KOH from -10 to 0.1 min, 0.1–2 mM from 0.1 to 3.3 min, 2–25 mM from 3.3 to 13.3 min, 25–65 mM from 13.3 to 20 min, 65 mM from 20 to 25 min
Flow Rate:	15 µL/min
Inj. Volume:	0.4 µL
Column Temp.:	30 °C
Detection:	Suppressed conductivity, Dionex ACES 300 Anion Capillary Electrolytic Suppressor, recycle mode
Samples:	A: Apple juice, B: Orange juice
Sample Prep.:	1:40 dilution, filter, 0.45 µm





Inorganic anions and organic acids in diluted fruit juice samples.

Peaks:	A	B
1. Quinate	6	2 mg/L
2. Glycolate	0.2	—
3. Lactate	5	3
4. Acetate	—	0.1
5. Formate	0.1	0.7
6. Pyruvate	0.3	—
7. Galacturonate	0.4	—
8. Chloride	0.3	1
9. Nitrate	—	0.4
10. Glutarate	—	4
11. Malate	40	25
12. Maleate	—	0.1
13. Sulfate	2	2
14. Oxalate	0.1	4
15. Phosphate	3	7
16. Citrate	0.1	125
17. Isocitrate	—	—
18. *cis*-Aconitate	—	—
19. *trans*-Aconitate	—	—

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Download Application Brief 137: Determination of Inorganic and Organic Acids in Apple and Orange Juice Samples using Capillary IC

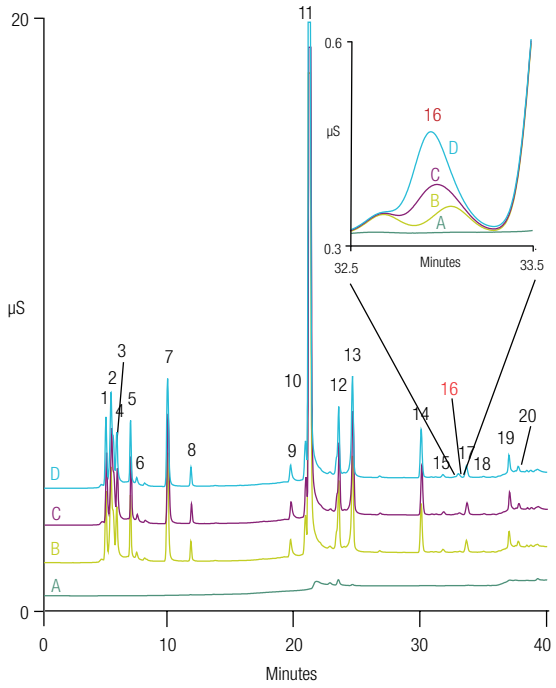
Total Inorganic Arsenic in Fruit Juice

Growing interest around arsenic (As) determinations in fruit juices has been triggered by media claims of total arsenic concentrations above acceptable limits in apple juice products. Although the FDA has been testing and monitoring fruit juices for arsenic content for more than 20 years and has found that total inorganic arsenic levels in juice are typically low, more recently there has been heightened scrutiny of arsenic in apple juice. The U.S. EPA has set the total arsenic standard for drinking water at 0.010 parts per million (ppm). However, total arsenic determinations can be misleading because inorganic arsenic compounds (arsenate As(V) and arsenite As(III)) are highly toxic, whereas organic arsenic compounds have much lower toxicity.

This technical note demonstrates that high-pressure capillary IC with suppressed conductivity detection (CD) provides a sensitive method to detect and quantify organic acids and arsenate (As(V)), which represents total inorganic arsenic because of the conversion of any arsenite present to arsenate. With an arsenate LOD of 0.026 mg/L and LOQ of 0.088 mg/L, this method can be used to estimate the total inorganic arsenic (As) in juice at a LOD of 0.014 mg/L and LOQ of 0.047 mg/L, which is well below the EPA reported Lowest-Observed-Adverse-Effect-Level (LOAEL) of 0.17 mg/L.

Peak	mg/L	Peak	mg/L
1. Quinate	6.2	11. Malate/Succinate	73.5
2. Fluoride	1.0	12. Sulfate	1.5
3. Lactate	2.1	13. Oxalate	2.1
4. Acetate/Glycolate	3.7	14. Phosphate	3.9
5. Formate	2.6	15. Unknown	–
6. Pyruvate	0.4	16. Arsenate*	
7. Galacturonate	15.7	17. Citrate	0.5
8. Chloride	0.3	18. Isocitrate	0.2
9. Nitrate	1.1	19. *trans*-Aconitate	0.3
10. Glutarate	0.3	20. Unknown	–

Note that the inset is a zoomed in view of the arsenate peak.



Inorganic anions, organic acids, and arsenate in a diluted apple juice sample.

Ion Chromatography	
Instrument:	Thmermo Scientific™ Dionex™ ICS-5000⁺ HPIC™ system
Column:	Dionex IonPac AS11-HC-4µm column (0.4 × 250 mm)
Column Temp.:	30 °C
IC Cube Temp.:	15 °C
Eluent Source:	Dionex EGC KOH Cartridge (Capillary)
Gradient:	1.5 mM KOH (-10–0 min); 1.5–2 mM KOH (0–2 min); 2–8 mM (2–13 min); 8–28 mM (13–25 min); 28–35 mM (25–33 min); 35–65 mM (33–34 min); 65 mM (34–38 min)
Flow Rate:	0.015 mL/min
Inj. Volume:	0.40 µL
Detection:	Suppressed conductivity, AutoSuppression, Dionex ACES 300 suppressor, recycle mode, 13 mA
System Backpressure:	~3000 psi
Samples:	A: Water B: 50-fold dilution of apple juice Sample 1 C: 0.2 mg/L arsenate spiked Sample B D: 0.5 mg/L arsenate spiked Sample B

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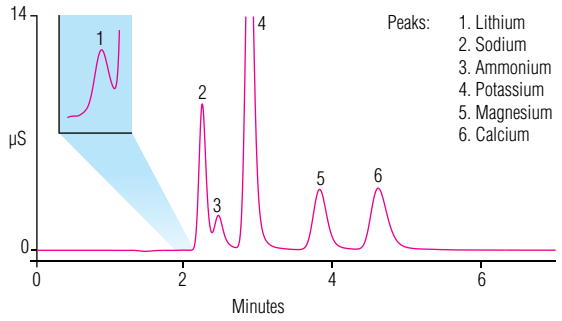
Download Technical Note 145: Determination of Total Inorganic Arsenic in Fruit Juice Using High-Pressure Capillary Ion Chromatography

Cations in Fruit Juices

Determining cations, such as potassium, sodium, and calcium, in fruit juices is important due to their dietary significance. For example, recent studies have supported the contention that excess dietary sodium is a contributing factor in heart disease. Calcium, though an important dietary component for most, can be an issue for patients with renal insufficiency. Potassium is also essential for good health and is present in significant concentrations in some juices. For these reasons, accurate reporting of cation concentrations is helpful.

A simple method to determine cations in fruit juices requires only a 1:100 dilution followed by injection. Inline sample filtration helps protect analytical columns from clogging by particulates. The method is sensitive enough to determine lithium ion concentration at low µg/L levels with sufficient resolution even in the presence of mg/L concentrations of sodium. Analysis time is 7 min or less.

Conditions	
Inline Filter:	0.5 µm low volume filter and housing
Column:	Dionex IonPac CS12A 2 × 250 mm column
Eluent:	12.5 mM Methanesulfonic Acid
Flow Rate:	0.4 mL/min
Column Temp.:	30 °C
Detection:	Suppressed conductivity, 40 °C cell temp Thermo Scientific™ Dionex™ CSRS™ 300 Cation Self-Regenerating suppressor, 2 mm, 30 mA, recycle mode
Injection Volume:	25 µL



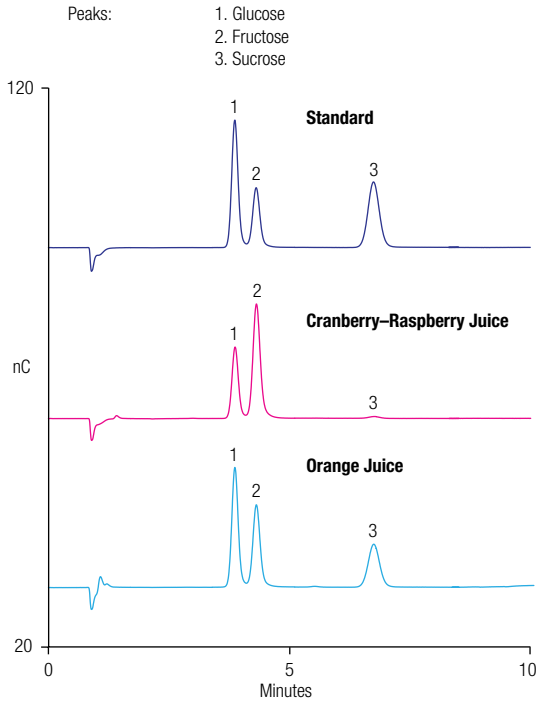
Example chromatogram of apricot nector (1:100 dilution). Note lithium peak, 30 µg/L, and sodium peak, 120 mg/L.

Carbohydrates in Fruit Juice

HPAE coupled with PAD is a well-established technique to identify and quantify carbohydrates in food and beverage samples. This technique is important for quality control, nutritional labeling, authenticity testing, and production process monitoring because it provides key metrics of product quality and related properties, contamination, and adulteration. HPAE-PAD allows direct quantification of non-derivatized carbohydrates with minimal sample preparation and esolves most carbohydrates from sugar alcohols and organic acids, while not detecting sodium chloride commonly present in fruit juices.

In this application brief, glucose, fructose, and sucrose in fruit juices are well resolved using a Dionex CarboPac PA20 column in capillary format and an electrolytically generated potassium hydroxide eluent. Capillary Reagent-Free™ ion chromatography (RFIC™) systems expand the application of IC to carbohydrate analysis for the food and beverage industries by bringing enhanced mass sensitivity, ease-of-use, and reproducibility to routine determination of carbohydrates.

Conditions	
Column:	Dionex CarboPac PA 20, 0.4 × 150 mm
Temperature:	30 °C
Eluent:	50 mM potassium hydroxide (EG)
Flow Rate:	10 µL/min
Inj. Volume:	0.40 µL
Detection:	PAD, 4–potential carbohydrate, Au
Ref. Electrode:	PdH
Gasket Thickness:	25 µm
Samples:	Juice samples (5000× dilution) Standard (20 µM)



Analysis of juices for carbohydrates by capillary HPAE-PAD.

Download Application Brief 127: Determination of Carbohydrates in Fruit Juice using Capillary High-Performance Anion-Exchange Chromatography

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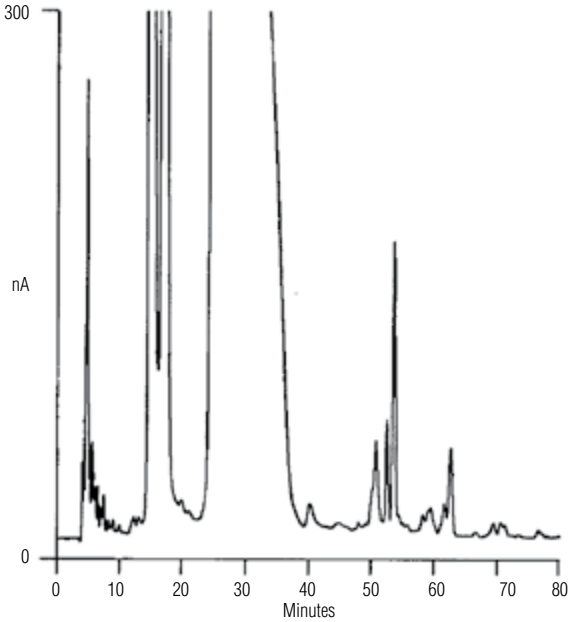
Fruit Juice Adulterated with Medium Invert Sugar

Fruit juice adulteration presents an economic and regulatory problem. The United States orange juice industry estimates that orange juice sales gross more than one billion dollars annually. The most common forms of adulteration include simple dilution and blending of inexpensive and synthetically produced juices into the more expensive ones. The source of sweetener can be juices from other fruits or vegetables. Beets produce sugar via a metabolic pathway different from sugar cane and similar to that of many fruits.

Investigators using HPAE-PAD have discovered several components in beet medium invert sugar that are not present in orange juice. The selectivity of anion-exchange chromatography, especially for oligosaccharides, and the sensitivity and specificity of pulsed amperometric detection make HPAE-PAD uniquely suited to this analysis



Orange juice adulterated with medium invert sugar. Note the late-eluting fingerprint between 50 and 60 minutes.

Conditions				
Columns:	2 Dionex CarboPac PA1, 4 × 250 mm			
Eluent 1:	0.1 M Sodium hydroxide			
Eluent 2:	0.1 M Sodium hydroxide, 0.1 M Sodium acetate			
Eluent 3:	0.3 M Sodium hydroxide			
Gradient:	Time	%E1	%E2	%E3
	0–4 min	100	0	0
	4–20	100–97	0–3	0
	20–50	97–0	3–100	0
	50–60	0	100	0
	60	0	0	100
	All gradient steps are linear (AGP curve 5)			
Flow Rate:	0.70 mL/min			
Inj. Vol.:	100 µL			
Expected Pressure:	1400–2000 psi (10–14 MPa)			
Postcolumn Reagent:	0.3 M Sodium hydroxide			
Postcolumn Flow Rate:	0.8 mL/min			
Detection:	Pulsed amperometry, gold working electrode			
	PAD Settings:			
	t(ms)	**E(volt)***		
	120	0.05		
	120	0.80		
	420	–0.60		

*Potentials are referenced to Ag/Ag(I). Today we would use different time and voltage conditions. Please see Technical Note21.

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Download Application Note 82: Analysis of Fruit Juice Adulterated with Medium Invert Sugar from Beets

Sugar Alcohols in Confections and Fruit Juices

Sugar alcohols are used in confectionary products because they impart a sweet taste without the calories associated with sugars. Sorbitol (60% as sweet as sucrose) and mannitol are sugar alcohols commonly used as replacements for sucrose in dietetic candy.

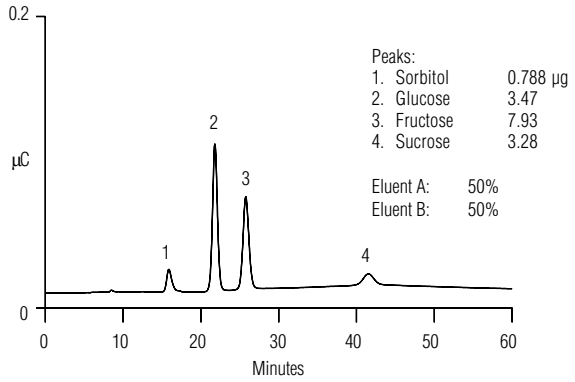
The Dionex CarboPac MA1 column is the preferred column for the determination of sugar alcohols. It yields excellent resolution and is used with pulsed amperometric detection to determine sugar alcohols with high sensitivity and specificity without derivatization or the addition of a postcolumn reagent. This column operates at ambient temperatures to promote ease-of-use and an increased lifetime. As with other Dionex CarboPac columns, the Dionex CarboPac MA1 column exhibits long-term reproducibility and durability.

Conditions	
Columns:	Dionex CarboPac MA1, 4 × 250 mm
Expected Operating Pressure:	5.5 to 7.6 MPa (800 to 1100 psi)
Injection Volume:	10 µL
Eluents:	A: Deionized water B: 1.0 M Sodium hydroxide
Flow Rate:	0.4 mL/min
Detection:	Pulsed amperometry, gold working electrode

Thermo Scientific Dionex ED40 Electrochemical Detector Settings as follows*:

t (ms)	E (volts)	Integration (s)
400	+0.05	0.2–0.4
200	+0.75	
400	–0.15	

* See Technical Note 21 for a discussion of pulse potentials.



Diluted apple juice containing sorbitol.

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Carbonated Beverages

Determination of organic acids and carbohydrates in carbonated beverages is important due to their influence on flavor, freshness, and overall palatability, in addition to meeting more detailed product labeling requirements. Fast, reproducible, and simple methods have been developed for organic acids using IC with conductivity detection and for sugars, such as mono and disaccharides, using HPAE-PAD.

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Applications

- Phosphate and Citrate in Carbonated Beverages
- Anions and Organic Acids in a Carbonated Beverage
- Monosaccharides and Disaccharides in Beverages

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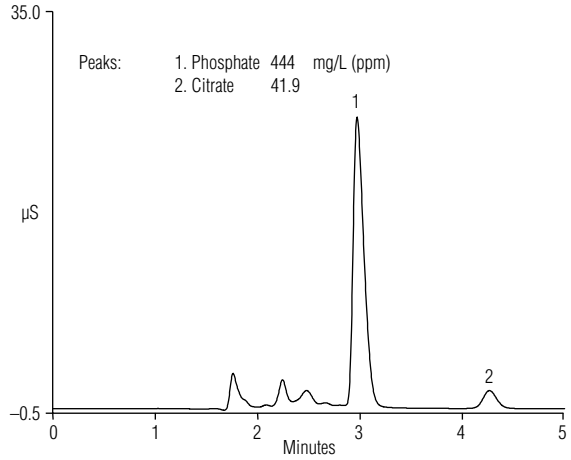
Phosphate and Citrate in Carbonated Beverages

Soft drinks are complex mixtures containing a variety of substances such as coloring compounds, flavoring agents, acidifiers, sweeteners, preservatives, and caffeine. Acidulants reduce the soft drink's pH and therby assist in beverage preservation for long-term storage. The most common acidulants used in soft drinks are phosphoric and citric acids. Phosphoric acid is more effective in lowering the pH than organic acids, while citric acid produces a stronger tartness. Phosphoric acid is commonly found in colas whereas citric acid is typically added to fruit flavored beverages.

In this application note, method using an RFIC system, a low capacity hydroxide-selective Dionex IonPac Fast Anion III column with suppressed conductivity detection is a simple, rapid, accurate, precise, and rugged approach for the simultaneous determination of phosphate and citrate in carbonated soft drinks. This method is a significant improvement in comparison to the AOAC colorimetric assay by eliminating the use of additional reagents and unneccessary dilutions of cola samples that can result in poor precision and accuracy.



Determination of phosphate and citrate in low carbohydrate Cola A on the Dionex IonPac Fast Anion III column.

Conditions	
Columns:	Dionex IonPac Fast Anion III Analytical, 3 × 250 mm**
Eluent:	20 mM potassium hydroxide
Eluent Source:	Dionex ICS-2000 EG system with Dionex CR-ATC column
Flow Rate:	1.0 mL/min
Temperature:	30 °C
Inj. Volume:	1.2 µL
Detection:	Suppressed conductivity, Dionex ASRS ULTRA II suppressor 2 mm, recycle mode, 70 mA
Background Conductance:	<1 µS
System Backpressure:	~2300 psi
Run Time:	5 min (6 min injection-to-injection)

* This application note is also applicable to other RFIC systems. Equivalent or improved results can be achieved using a Thermo Scientific Dionex ICS-2100 system.

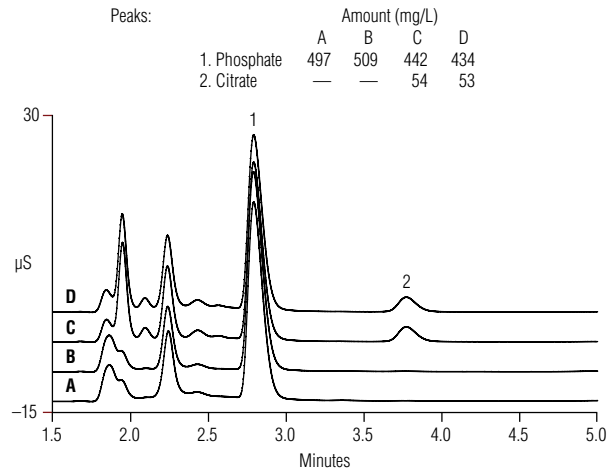
** Note: The guard column was eliminated for this application to increase the analysis speed. Adding the guard column will increase the run time by approximately 6%.

Phosphate and Citrate in Carbonated Beverages

Phosphoric and citric acids are critical additives to colas for flavor and preservation. Carbon dioxide is added for flavor or effervescence and also acts as a preservative. When samples are analyzed by ion chromatography (IC) with hydroxide and tetraborate eluents, carbonate in the sample can sometimes coelute and interfere with the quantification of an anion of interest. The gas bubbles from the carbonation also cause variability in the amount injected, resulting in poor peak area reproducibility. Carbonation must be removed to achieve precise and accurate phosphate and citrate determinations.

In this application update, using a Dionex CRD device to remove cola carbonation adds ~2.5 min to the total analysis time while retaining the precision (RSD <0.15% for retention time), linearity (r^2 > 0.999), and reproducibility (RSD <0.3%) of the original method. This eliminated the extra sample handling and the 20 min required for off-line degassing. Although only colas were analyzed, this sample preparation method can be used with other acidic carbonated samples.

Conditions	
Columns:	Dionex IonPac Fast Anion III, 3 × 250 mm Dionex IonPac Guard, 3 × 50 mm
Flow Rate:	1.0 mL/min
Eluent:	Dionex EluGen KOH cartridge, 20 mM Potassium hydroxide
Temperature:	30 °C
Inj. Volume:	1.2 µL
Sample Prep:	4 mm Dionex CRD device installed between autosampler and injection port
Detection:	Suppressed conductivity, in recycle mode, 70 mA
Background:	<1 µS
Backpressure:	~2100 psi
Typical Noise:	<1.6 nS
Run Time:	5 min

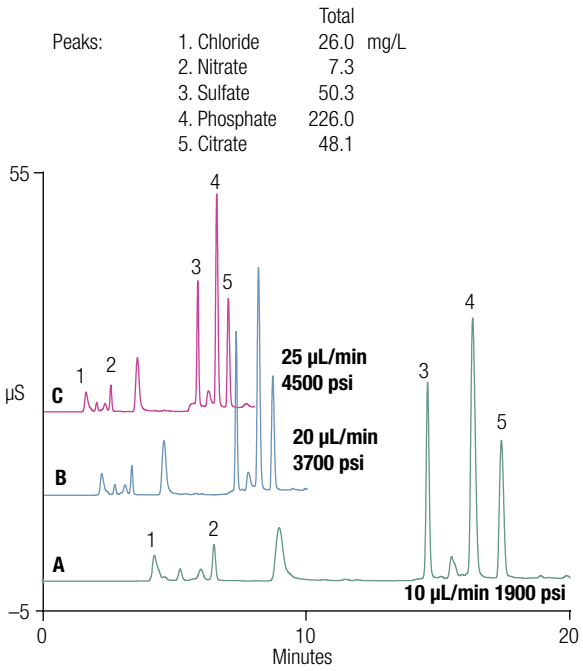


Colas with carbonate removed on-line and off-line.

Anions and Organic Acids in a Carbonated Beverage

Determinations of organic acids in beverages are important to the beverage industry because these acidulants and flavoring agents maintain beverage freshness, minimize microbiological growth, and add a characteristic flavor. Additionally, analysis is required to meet product labeling requirements in 21 CFR part 101.

This application demonstrates the power of using higher flow rates on a high-resolution column and a capillary IC system capable of high system pressures, such as the high-pressure Dionex ICS-5000⁺ capillary HPIC system. Sample throughput is increased by increasing the flow rate, saving money and labor.



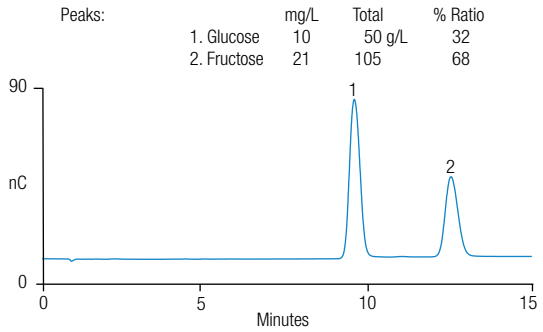
Fast separations of anions in a diet cola beverage by high-pressure capillary IC.

Conditions	
Columns:	Dionex IonSwift MAX 200, 0.25 × 250 mm
Eluent Source:	Dionex EGC KOH Capillary Cartridge with Dionex CR-ATC column (capillary)
Gradient:	A: 2 mM KOH for 0.1 min, 2–10 mM (0.1–10 min), 10–50 mM (10–15 min) B: and C: Same gradient adjusted for flow rate
Flow Rate:	A: 10; B: 20; C: 25 µL/min
IC Cube Temp.: *	30 °C
Compartment Temp.:	15 °C
Inj. Volume:	0.4 µL
Detection:	Suppressed conductivity, Dionex ACES 300 Anion Capillary Electrolytic Suppressor, Thermo Scientific Dionex CRD 200 Carbonate Removal Device (Capillary), recycle mode, A: 8 mA; B: 15 mA; C: 18 mA
Background Conductance:	0.5–0.8 µS conductance
Noise:	< 0.3 nS
System Backpressure:	A: 1900 psi; B: 3700 psi, C: 4500 psi

Monosaccharides and Disaccharides in Beverages

Mono- and disaccharide sugar determinations are often used in the food and beverage industry to ensure the quality of a formulated product, to maintain or select for desired sweetness, and to characterize and confirm the source of the carbohydrates. Carbohydrates have poor chromophores and are therefore problematic to detect by UV absorption without lengthy and costly derivitization. However, carbohydrates can be determined directly by HPAE-PAD, a well-established method that eliminates the need for derivitization, saving time and money, including reagent costs.

This application demonstrates mono- and disaccharides determinations in two-fold to 10,000-fold diluted beverage samples by HPAE-PAD at capillary flow rates on the Thermo Scientific™ Dionex™ ICS-4000 HPIC™ Integrated Capillary System.



Glucose and fructose in a carbonated beverage.

Conditions	
Columns:	Dionex CarboPac PA20 column set (0.4 × 150 mm)
Eluent Source:	Dionex EGC KOH Eluent Generator Cartridge (Capillary)
Eluent:	10 mM KOH (-7 to 20 min)
Flow Rate:	0.008 mL/min
Column Temp.:	30 °C
Compartment Temp.:	27 °C
Inj. Volume:	0.4 µL
Detection:	PAD, Gold on PTFE, 0.001" or 0.015" gasket, Four-Potential Carbohydrate waveform
Reference Electrode:	pH-Ag/AgCl
Background:	10–20 nC
Noise:	< 10 pC

* Column wash/10 samples: 5 min at 100 mM KOH, 12 min equilibration at 10 mM KOH.

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

Alcoholic Beverages

Wine and beer are complex samples that contain numerous components including carbohydrates, inorganic anions and cations, and organic acids. These can be introduced from the water used, extracted from the brewing ingredients, generated in the fermentation process, or added to achieve a desired characteristic flavor, aroma, or coloring. IC with conductivity detection and HPAE-PAD are used to monitor these components during production to ensure consistent quality.

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Applications

- Inorganic Ion, Organic Acid, and Carbohydrate Determinations in Beer
- Organic Acids in Lager-Style Beer
- Organic Acids in Fruit Juices and Wines
- Total and Free Sulfite in Food and Beverages

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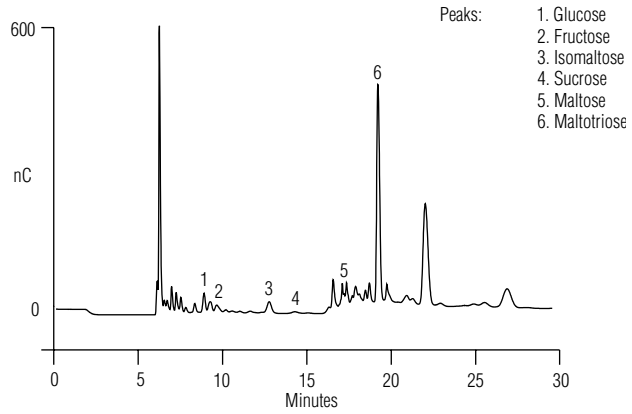
Inorganic Ion, Organic Acid, and Carbohydrate Determinations in Beer

Ion chromatography is an efficient technique for the analysis and quantification of ions in solution. The compounds of interest for the beer industry range—from inorganic ions, organic acids, and hop bittering principles that contribute to the overall taste and bitterness of the beverage—to proteins, carbohydrates, and alcohols that are monitored to determine the extent of fermentation. The finished beer product may also be analyzed to determine the concentration of added preservatives and colorants.

This application note describes the use of ion-exchange or ion-exclusion chromatography for the determination of five classes of compounds of interest to the brewing industry, including: carbohydrates, alcohols, organic acids, inorganic anions, and inorganic cations. One of two forms of detection is used, pulsed amperometry or conductivity detection.

Conditions				
Column:	Dionex CarboPac PA1 (4 x 250 mm)			
Eluent 1:	Deionized water			
Eluent 2:	500 mM Sodium hydroxide			
Gradient:	**Time**	**E1**	**E2**	**Comments**
	Initial	99	1	Reequilibrate
	5.00	99	1	Inject
	6.00	99	1	Back to Load
	20.00	91	9	
	45.00	0	100	
	50.00	0	100	
Flow Rate:	1.0 mL/min			
Inj. Volume:	10 µL			
Detection:	Pulsed amperometry, gold electrode			



Separation of mono-, di-, and trisaccharides in an American beer by ion-exchange chromatography with pulsed amperometric detection. The sample was diluted 1:10 before injection.

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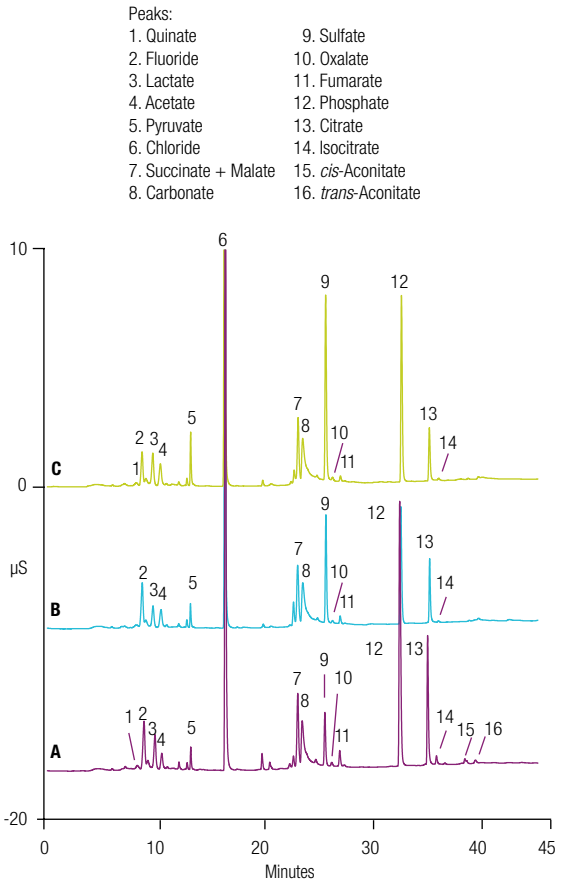
Download Application Note 46: Ion Chromatography: A Versatile Technique for the Analysis of Beer

Organic Acids in Lager-Style Beer

Beer production has been of interest since the beginnings of civilization with brewing processes advancing along with society. Beer is a complex sample matrix that contains numerous components including proteins, carbon dioxide, carbohydrates, inorganic anions and cations, aldehydes, organic acids, and ethanol. These can be passively introduced from the minerals in the water, extracted from the brewing ingredients, generated in the fermentation process, or added to achieve a desired characteristic flavor. Organic acids are end products of yeast fermentation critical to the flavor of beer, but are also products of bacterial fermentation that introduce a sour flavor, either purposely or unintentionally due to spoilage.

This Technical Note presents the advantages of the 4 µm particle-size Dionex IonPac AS11-HC-4µm column combined with the Dionex ICS-5000$^+$ HPIC system for optimal separation of organic acids and inorganic anions in beer samples using electrolytically generated hydroxide eluent.



Analysis of beer samples

Conditions	
Column:	Dionex IonPac AS11-HC-4µm and guard, 4 mm i.d.
Eluent Source:	Dionex EGC 500 KOH cartridge
Eluent:	Potassium hydroxide
Gradient:	1 mM KOH (-5–8 min), 1–15 mM KOH (8–18 min), 15–30 mM KOH (18–28 min), 30–60 mM KOH (28–38 min), 60 mM KOH (38–45 min)
Inj. Volume:	10 µL
Flow Rate:	1.5 mL/min
Temperature:	30 °C
Detection:	Suppressed conductivity, Thermo Scientific™ Dionex™ AutoSuppression™ Device, Dionex AERS 500 suppressor recycle mode or external water mode (3–5× eluent flow)
Background Conductance:	< 1.0 µS-cm-1
Peak-to-Peak Noise:	< 3 nS
System Backpressure:	< 4500 psi

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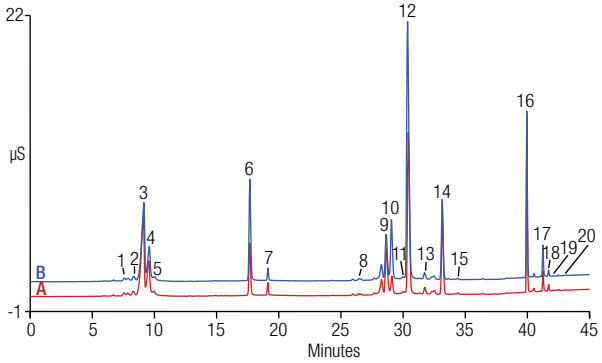
Download Technical Note 126: Determination of Organic Acids in Beer Samples Using a High-Pressure Ion Chromatography System

Organic Acids in Fruit Juices and Wines

Organic acids play important roles in juices and wines because of their influence on the organoleptic properties (flavor, color, and aroma) as well as the stability and microbiological control of the products. The total content of organic acids in juices and wines affects the drink's acidity, whereas the levels of a specific organic acid can directly influence the flavor and taste of the drink. Therefore, organic acid profiles are monitored to determine the freshness of certain fruit juices; winemakers also monitor the concentration of various organic acids to ensure the quality of their wines.

This study presents the characterization of ionic composition profiles in fruit juices and wines and the determination of organic acids in a selection of juice and wine samples. The separation of 30 anions on the Dionex IonPac AS11-HC (9 µm) column and the Dionex IonPac AS11-HC-4 µm column sets are compared. The Dionex IonPac AS11-HC-4 µm column set offers superior resolving power for separation of the target anions. The suppressed conductivity detection offers high sensitivity for the anions, including various organic acids—even those present at low concentrations. The specificity and sensitivity of this method allow simple sample treatments without complex procedures such as extraction and/or derivatization.

Peaks:		A	mg/L	B			
	1. Quinate	4.31		4.31	11. Carbonate	—	—
	2. Fluoride	0.508		0.508	12. Tartrate	99.6	193
	3. Lactate	79.9		79.9	13. Maleate	5.31	5.31
	4. Acetate	21.3		21.3	14. Sulfate	20.1	20.1
	5. Glycolate	2.05		2.05	15. Oxalate	0.145	0.145
	6. Galacturonate	59.7		120	16. Phosphate	42.6	42.6
	7. Chloride	1.41		1.41	17. Citrate	4.61	8.76
	8. Nitrate	0.578		0.578	18. Isocitrate	1.96	1.96
	9. Succinate	33.2		33.2	19. *cis*-Aconitate	0.450	0.450
	10. Malate	11.2		43.3	20. *trans* Aconitate	0.0626	0.0626



(A) Merlot wine and (B) spiked Merlot wine with a 5% signal offset applied.

Conditions			
Columns:	Dionex IonPac AS11-HC-4 µm Guard, 2 × 50 mm (P/N 078036)		
	Dionex IonPac AS11-HC-4 µm Analytical, 2 × 250 mm (P/N 078035)		
Eluent Source:	Dionex EGC 500 KOH Eluent Generator Cartridge with Dionex CR-ATC 500 Continuously Regenerated Anion Trap Column		
Eluent A:	DI Water		
Eluent B:	CH_3OH		
Time (min)	KOH (mM)	Time (min)	B (%)
-2.00	1	-2.00	8
0.00	1	0.00	8
10.07	1	19.00	8
10.07	1	20.00	11
24.00	15	30.00	11
24.01	15	31.00	8
35.00	27	33.00	8
40.00	60	33.01	0
44.00	60	44.00	0
44.01	1	44.01	8
45.00	1	45.00	8
Flow Rate:	0.4 mL/min		
Inj. Volume:	2.5 µL		
Detection:	Suppressed Conductivity, Dionex ASRS 300 Anion Self-Regenerating Suppressor (2 mm), 82 mA, external water mode		
System Backpressure:	~3900 psi (1 mM KOH/8% CH3OH), ~4800 psi (60 mM KOH/11% CH3OH)		
Background Conductance:	~0.16–0.7- µS		
Noise:	~0.6–0.9 nS/min, peak-to-peak		
Run Time:	47 min		

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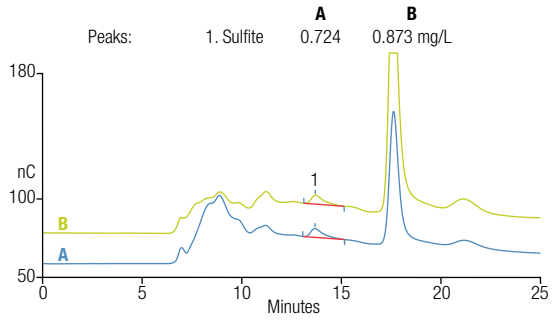
Download Application Note 1068: Determination of Organic Acids in Fruit Juices and Wines by High-Pressure IC

Total and Free Sulfite in Food and Beverages

In the food and beverage industries, sulfites are a group of compounds that includes sulfur dioxide and sulfite salts. Sulfites can occur naturally in some foods and beverages due to fermentation. For centuries, sulfiting agents—such as sodium sulfite, sodium bisulfite, and sodium metabisulfite—have been used as preservatives to prevent microbial spoiling and browning reactions in a wide variety of food and beverage products. Sulfiting agents can undergo a series of different reactions in food/beverage matrices, producing various species— including sulfite, bisulfite, metabisulfite, and other sulfite-related forms—that are either reversibly or irreversibly bound to food/beverage constituents, depending on the pH of the food/beverage.

In this application note, the determination of free and total sulfite in a selection of food and beverage samples is demonstrated. This method replaces the conventional Pt working electrode described in the archived version of AN 54 with a disposable Pt working electrode, which demonstrates good stability and does not require polishing. A smaller-dimension column set is used, which operates with a lower flow rate that significantly reduces eluent consumption. This updated method also can be applied to food and beverage samples with lower sulfite concentrations than those addressed in the archived version of AN 54.

Conditions	
Columns:	Dionex IonPac ICE-AS1 Guard, 4 × 50 mm Dionex IonPac ICE-AS1 Analytical, 4 × 250 mm
Eluent:	20 mM MSA
Temperature:	25 °C (upper compartment, detector) 30 °C (lower compartment, column)
Tray Temp:	4 °C
Detection:	PAD, disposable Pt working electrode
Run Time:	25 min



Chromatograms of A) total and B) free sulfite in red wine. A 15% signal offset has been applied.

Milk and Diary-Based Beverages

Milk-based beverages are distinct in that they naturally contain the sugar lactose. Because some people are unable to fully digest this sugar, most dairy products are required to carry a label indicating its presence. HPAE-PAD is the preferred technology for determining lactose and the heat-induced by-product, lactulose. Infant formula is a dairy-based beverage that is subject to very stringent regulations and for which specific IC methods have been developed to determine anions such as iodide, iodate, and the cation choline.

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Milk and Diary-Based Beverages

Applications

- Lactose and Lactulose in Milk Products
- Lactose in Lactose-Free Milk Products
- Myo-Inositol in Infant Formula and Adult Nutritionals
- Infant Formula Sialic Acids
- Iodide and Iodate in Infant Formula
- Choline in Infant Formula
- Choline in Infant Formula and Adult Nutritionals

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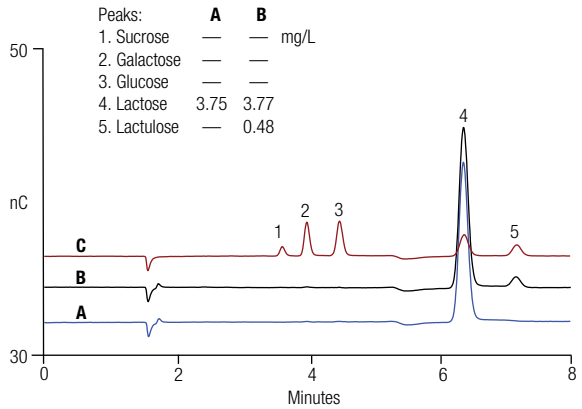
Lactose and Lactulose in Milk Products

Lactose and lactulose are important components in milk-based products. Lactose is the major milk disaccharide which is metabolized with the aid of lactase to the monosaccharides glucose and galactose.

Lactose has been determined by many methods including photometric, polarimetry, and fluorometry, but these methods are time consuming and not specific for lactose and lactulose. AOAC Method 984.15 uses enzymatic hydrolysis of lactose at pH 6.6 by β-galactosidase. This method is also time consuming, requires extensive reagent preparations, and is not sufficiently sensitive for the determination of lactose in lactose-free samples. HPAE-PAD is a well established sensitive method that selectively and directly determines carbohydrates, such as lactose and lactulose.

Conditions	
Column:	Dionex CarboPac SA10 guard and Dionex CarboPac SA10-4µm separation columns, 4 × 250 mm
Eluent:	4 mM KOH from -3 to 8 min
Eluent Source:	Dionex EGC 500 KOH cartridge
Flow Rate:	1.45 mL/min
Injection Volume:	10 µL
Column Temp.:	35 °C
Detection:	PAD, Four-Potential Carbohydrate waveform
Working Electrode:	Gold on PTFE Disposable Electrode
Reference Electrode:	pH-Ag/AgCl
Detection Temp.:	20 °C
Autosampler Temp.:	10 °C
Background:	20–40 nC
Noise:	< 20 pC
System Backpressure:	4800 psi
Sample:	A: Raw unpasteurized milk, B: A + 0.5 mg/L lactulose C: 0.5 mg/L carbohydrate standards



Lactose and lactulose in raw pasteurized milk.

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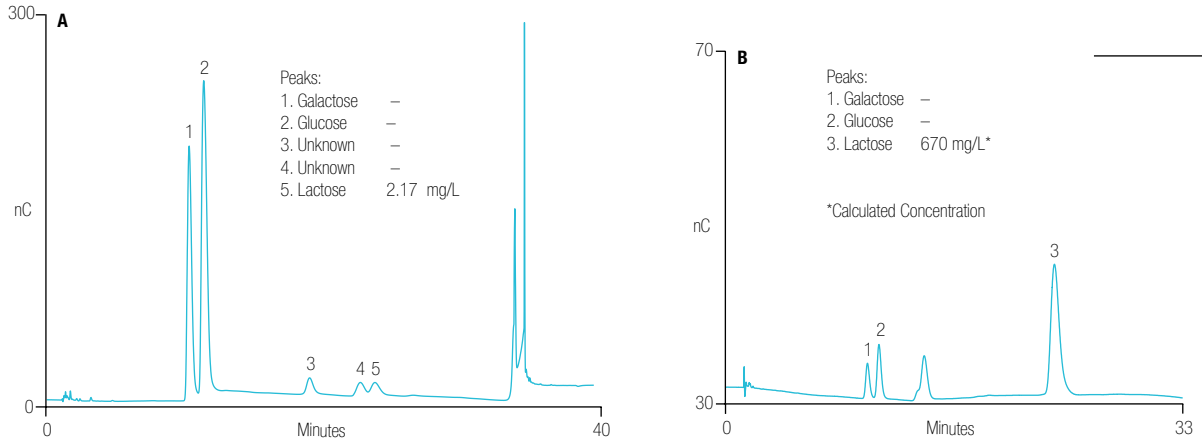
Download the Technical Note 146: Fast Determinations of Lactose and Lactulose in Milk Products Using HPAE-PAD

Lactose in Lactose-Free Milk Products

Lactose is the major disaccharide found in milk products and is catabolized into glucose and galactose by the enzyme lactase. Lactose-intolerant individuals have a lactase deficiency; therefore, lactose is not completely catabolized. While lactose intolerance is not a dangerous condition, its global prevalence has created a large market for lactose-free products. Commercially available lactose-free products are produced by breaking down lactose into glucose and galactose by enzymatic hydrolysis. However, the resulting milk products contain varying amounts of residual lactose. This has created the need for simple, reliable, and accurate analytical methods to quantify lactose.

In this application note, the work describes a sensitive and accurate method to extract, separate, and quantify lactose and lactulose in milk-based products. The method uses a Dionex CarboPac PA20 column with PAD to quantify lactose and lactulose in a separation time of less than 30 min. The use of disposable gold electrodes provides the benefit of high electrode-to-electrode reproducibility and rapid equilibration upon installation.

Conditions	
Columns:	Dionex CarboPac PA20 Analytical Column, 3 × 150 mm Dionex CarboPac PA20 Guard Column, 3 × 30 mm
Flow Rate:	0.4 mL/min
Inj. Volume:	10 µL
Tray Temp:	4 °C
Detection:	Integrated pulsed amperometry, Au on PTFE disposable or conventional Au working electrodes
Waveform:	Carbohydrate (standard quad)
Background:	<20 nC
Noise:	30 to 80 pC
Temperature:	30 °C
Eluents:	A) Deionized water B) 200 mM NaOH C) 200 mM NaOH, 100 mM sodium acetate D) 200 mM NaOH, 1 M sodium acetate



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.

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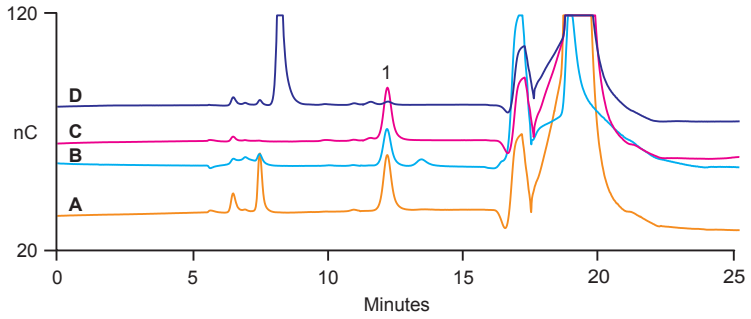
Download Application Note 248: Determination of Lactose in Lactose-Free Milk Products by High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection

Myo-Inositol in Infant Formula and Adult Nutritionals

Myo-inositol is one of the most abundant sugars in the body, where it occurs in its free form and as a component of phosphoinositides in cell membranes. It plays an important role in various biological functions, including the regulation of cell osmolality, phosphoinositide-mediated processes of cell signaling, formation of the neural system, and pulmonary surfactant phospholipid production.

In this application note, an HPAE-PAD method (AOAC Official Method 2011.18) is demonstrated to determine free and bound myo-inositol in infant formula and adult nutritional liquid samples. A column-switching technique is used to effectively remove the strongly retained carbohydrates in the sample matrix, thereby reducing run time. PAD with a Au on PTFE disposable electrode offers high sensitivity while eliminating the need for sample derivatization and electrode polishing.

Peak:	A	B	C	D	
1. Myo-inositol	1.00	0.904	0.878	0.0681	mg/L



Free myo-inositol in (A) SRM 1849, (B) milk-based powdered infant formula, (C) soy-based powdered infant formula, and (D) adult nutritional liquid. A 15% signal offset has been applied.

Conditions	
Dimension 1	
Column:	Dionex CarboPac PA1 Guard, 4 × 50 mm
Eluent:	750 mM Sodium Hydroxide (NaOH)
Flow Rate:	0.4 mL/min
Injection Volume:	20 µL
System Backpressure:	800–900 psi
Dimension 2	
Column:	Dionex CarboPac MA1 Guard, 4 × 50 mm Dionex CarboPac MA1 Analytical, 4 × 250 mm
Eluent:	15 mM KOH
Eluent Source:	Dionex EGC 500 KOH Cartridge with Dionex CR-ATC 500 Trap Column
Flow Rate:	0.4 mL/min
Injection Volume:	20 µL
Temperature:	30 °C
Detection:	PAD, Au on PTFE Disposable Working Electrode System
Backpressure:	2800–2900 psi
Background Conductance:	28–41 nC
Noise:	~16 pC/min peak-to-peak
Run Time:	25 min

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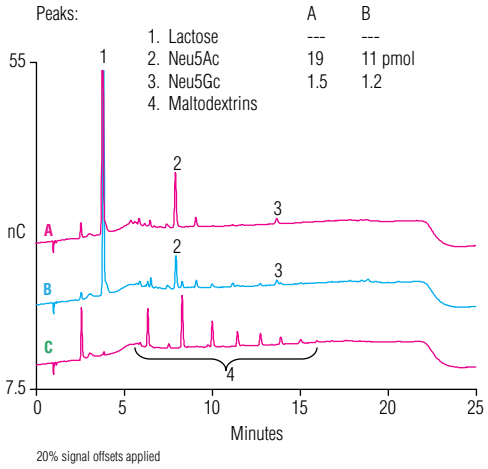
Download the Application Note 1083: Determination of Myo-Inositol (Free and Bound as Phosphatidylinositol) in Infant Formula and Adult Nutritionals

Infant Formula Sialic Acids

Dietary sialic acids are important for infant development, serving both immune system and cognitive development roles. Determination of sialic acids in a complex matrix, such as a dairy product, presents many challenges. The majority of sialic acids are found as part of a glycoconjugate rather than in the free form. In human milk, ~73% of sialic acids are bound to oligosaccharides, while some infant formulas have been shown to contain sialic acids primarily bound to glycoproteins.

Sialic acids in infant formulas are accurately determined by HPAE-PAD using the Dionex CarboPac PA20 column following acid hydrolysis and maltodextrin removal using one of two sample-preparation methods. HPAE-PAD provides reliable determination of sialic acids in acid-hydrolyzed infant formula samples without sample derivatization. This method may be used to quantify sialic acids in formulas that have been enriched with sialic acids.



Separation of anion-exchange resin prepared infant formula samples based on A) dairy, B) dairy with added maltodextrins, and C) soy with added maltodextrins.

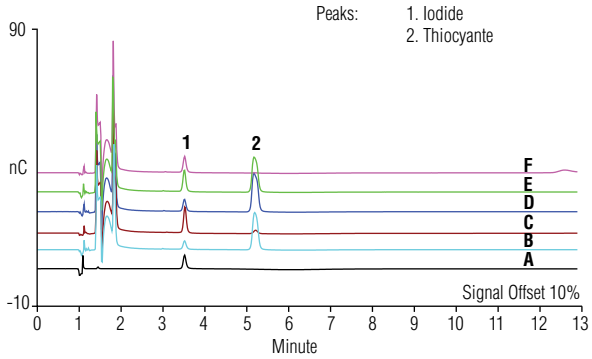
Conditions	
Columns:	Dionex CarboPac PA20, 3 × 150 mm Dionex CarboPac PA20 Guard, 3 × 30 mm
Eluent A:	100 mM NaOH
Eluent B:	400 mM sodium acetate in 100 mM NaOH
Eluent Gradient:	10 to 200 mM acetate in 100 mM NaOH from 0 to 15 min, 200 mM acetate in 100 mM NaOH from 15 to 20 min, 10 mM acetate in 100 mM NaOH from 20 to 25 min
Flow Rate:	0.5 mL/min
Temperature:	30 °C (column and detector compartments)
Inj. Volume:	10 µL
Detection:	Pulsed amperometric, disposable carbohydrate certified gold working electrode
Background:	16–25 nC (using the carbohydrate waveform)
Noise:	~20 to 50 pC
System Backpressure:	~2900 psi

Iodide and Iodate in Infant Formula

Iodine is an important micronutrient essential for the production of thyroid hormones that are involved in the regulation of many key biochemical reactions. Iodine deficiency can lead to varying degrees of growth and developmental abnormalities in children and adults, including such illnesses as goiter and cretinism. However, an excess of iodine can also lead to thyroid disorders, especially in infants. As iodine is primarily absorbed from our diet, supplementation of iodine in food is a common practice. The concentration of iodine in iodine-fortified foods is often regulated and monitored.

In this application note, a robust IC-PAD-based method is described for the accurate determination of iodide in milk-based infant formula from all major U.S. producers. This method was also accurate for determining iodide in one soy-based infant formula (additional soy-based formulas were not tested). The method uses a Dionex IonPac AG11/AS11 column set with nitric acid eluent and a silver working electrode. The sample preparation conditions were optimized for extracting the free and bound forms of iodide and also for reducing iodate to iodide to determine iodide and iodate (i.e., total iodine) in milk- and soy-based infant formulas.

Conditions	
Columns:	Dionex IonPac AG11 Guard, 4 × 50 mm Dionex IonPac AS11 Analytical, 4 × 250 mm
Flow Rate:	1.5 mL/min
Injection Volume:	100 µL
Column Temp:	30 °C
Backpressure:	1000 psi
Flush Volume:	1000 µL
Detection:	PAD
Cell Temp:	30 °C
Background:	2–10 nC
Working Electrode:	Silver working electrode
Reference Electrode:	
Mode:	Ag/AgCl mode
Noise:	3–5 pC



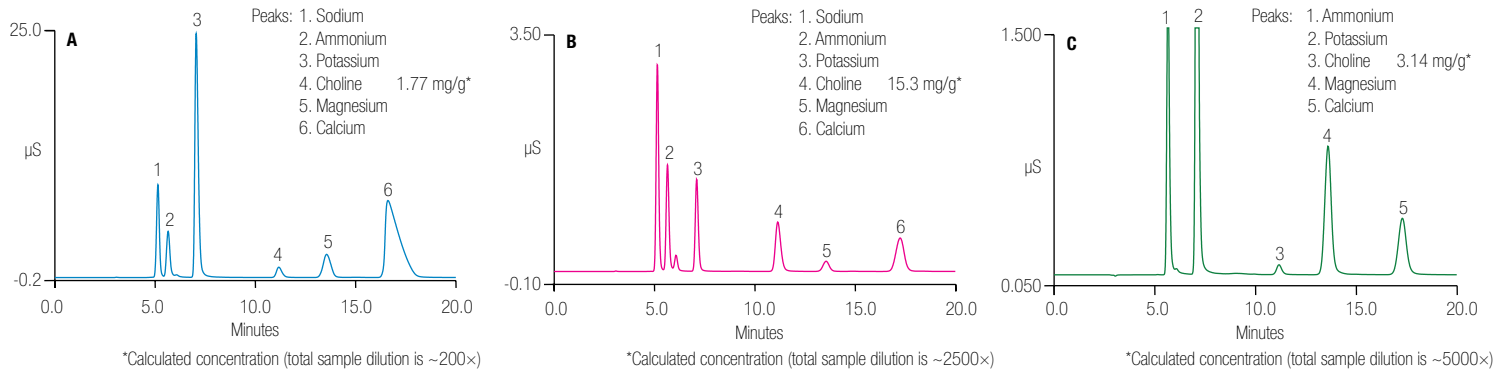
Determination of iodide in (A) DI water, (B-E) milk-based infant formulas, and (F) soy-based infant formula.

Choline in Infant Formula

Choline is a water-soluble micronutrient vital to cell membrane integrity, support of methyl group metabolism, and nervous system activity. It is present as free choline in small quantities in a wide variety of foods and frequently found in its esterified forms. Choline can also be found in fortified foods and dietary supplements; e.g., choline is a required additive in many infant formulas. It is therefore important to determine the choline content of common foods.

This study demonstrates an improvement in the IC method described in Application Note 124 for determining choline in infant formula and other food samples. A column set with optimized selectivity and a smaller dimension provides much improved efficiency for choline, and therefore better sensitivity. The electrolytically generated eluent replaces the manually prepared eluent, enhancing the level of automation and ease of operating the IC system and achieving a better S/N ratio. A slightly modified sample preparation procedure also increases sample throughput.

Conditions	
Columns:	Dionex IonPac CS19 Analytical, 2 × 250 mm Dionex IonPac CG19 Guard, 2 × 50 mm
Eluent:	Methanesulfonic Acid (MSA), 6.4 mM
Eluent Source:	Thermo Scientific Dionex EGC III MSA Cartridge with CR-CTC II Trap Column
Flow Rate:	0.25 mL/min
Inj. Volume:	5 µL
Sample Tray Temperature:	10 °C
Detection:	Suppressed Conductivity, Thermo Scientific™ Dionex™ CSRS™ 300 Cation Self-Regenerating Suppressor, 2 mm
System Backpressure:	~2350 psi
Background Conductance:	~0.100 µS
Noise:	~0.1 nS/min peak-to-peak



A) Determination of choline in infant formula, B) determination of choline in egg powder, and C) determination of choline in soy flour.

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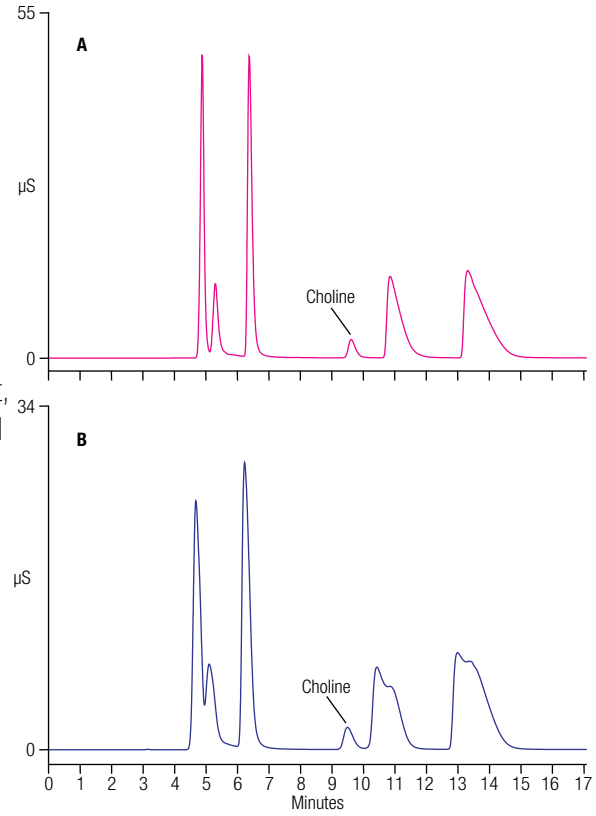
Download Application Update 189: Determination of Choline in Infant Formula and Other Food Samples by IC

Choline in Infant Formula and Adult Nutritionals

Choline is a water-soluble quaternary amine essential to methyl metabolism, transmembrane signaling, and normal brain development. Choline is present in many foods and also exists in esterified and bound forms: acetylcholine, phosphocholine, phosphatidylcholine, glycerophosphocholine, and sphingomyelin. The adequate intake (AI) for infants ages 0–12 months ranges from 125 to 150 mg/day whereas the AI for adult men, pregnant women, and lactating mothers ranges from 450 to 550 mg/day and the AI for adult women who are not pregnant or lactating ranges from ~400 to 425 mg/day. Although the body produces choline, a choline-rich diet is necessary to meet dietary needs. Therefore, infant formulas and adult nutritional products are fortified with choline.

In this application update, the Dionex IonPac CS19 column separates choline and other cations in the sample with excellent efficiency, allowing simultaneous determination of choline and other cations present in the samples. The RFIC system requires only a source of degassed DI water for generation of high-purity eluent, thus simplifying operation while increasing, precision and accuracy. Suppressed conductivity detection allows simple, robust, and accurate determination of choline in all samples with high sensitivity.



Infant formula sample (A) with and (B) without Thermo Scientific™ Dionex™ OnGuard™ II A Cartrdige treatment.

Conditions	
Columns:	Dionex IonPac CG19 Guard, 2 × 50 mm Dionex IonPac CS19 Analytical, 2 × 250 mm
Eluent:	–5 to 13 min 6.4 mM MSA, step to 25 mM MSA at 13 min, 25 mM MSA from 13–17 min
Eluent Source:	Dionex EGC III MSA Eluent Generator Cartridge with Dionex CR-CTC II Column
Flow Rate:	0.25 mL/min
Inj. Volume:	5 µL
Temperature:	30 °C
Autosampler Temperature:	10 °C
Detection:	Suppressed Conductivity, Dionex CSRS 300 Suppressor, 2 mm, Recycle Mode,–5–13 min 5 mA, 13–17 min 19 mA
System Backpressure:	~2200 psi
Background Conductance:	<0.2 µS
Typical Noise:	<0.2 nS
Equilibration Run Time:	17 min

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Download Application Update 193: Choline in Infant Formula and Adult Nutritionals, a Single Laboratory Validation

Coffee

The carbohydrates and organic acids in coffee play major roles in flavor determination and can be used as tracers to assess authenticity. For carbohydrates, HPAE-PAD is the method of choice, while IC with conductivity detection is preferred for determination of a broad range of organic acids.

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Applications

- Carbohydrates in Coffee
- Anions and Organic Acids in Brewed Coffee

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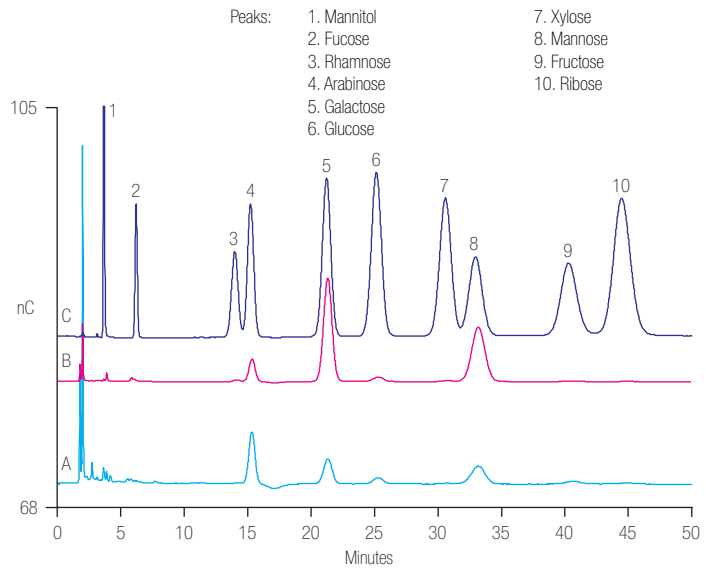
Carbohydrates in Coffee

Coffee carbohydrates constitute the major part (at least 50% of the dry weight) of raw coffee beans. The carbohydrates in coffee contribute to the flavor of the beverage as they undergo complex changes (react with amino acids, i.e., the Maillard reaction) during the roasting process. They act as aroma binders, foam stabilizers, and also impart viscosity to the coffee beverage. Carbohydrates are also good tracers for assessing the authenticity of soluble (instant) coffee.

In this application note, HPAE-PAD methods are demonstrated for the determination of carbohydrates in extracts from instant coffee and green coffee beans. Two methods (the AOAC Official Method 995.13 and a fast method using the Dionex CarboPac SA10 column) were compared.

Conditions	
Modified AOAC Official Method 995.13	
Columns:	Dionex CarboPac PA1 Analytical, 4 × 250 mm Dionex CarboPac PA1 Guard, 4 × 50 mm
Flow Rate:	1.0 mL/min
Inj. Volume:	10 µL (full loop)
Column Temp.:	25 °C
Detector Temp.:	30 °C
Back Pressure:	2400 psi
Eluent:	DI water from 0–50 min, 300 mM NaOH from 50–65 min DI water from 65–80 min (re-equilibration)
Postcolumn Base:	300 mM NaOH
Flow Rate for Postcolumn Base:	0.6 mL/min



Chromatograms of free carbohydrates extracted from instant coffee (A), total carbohydrates extracted 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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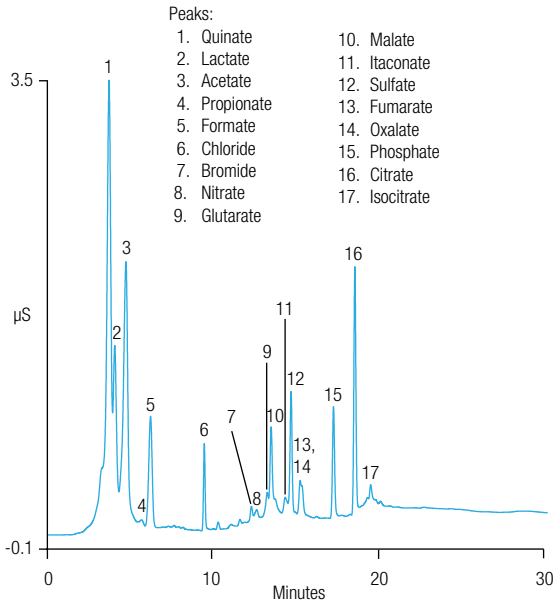
Download the Application Note 280: Carbohydrates in Coffee: AOAC Method 995.13 vs a Fast Ion Chromatography Method

Anions and Organic Acids in Brewed Coffee

Brewed coffee, one of the most popular beverages worldwide, is prepared from fermented and roasted coffee plant seeds (beans), typically *Coffea arabica* (Arabica). *Coffea canefora, variant robusta* (Robusta), provides a less desirable flavor, is less costly, and therefore is often blended or adulterated in Arabica to create less expensive coffees or to increase profits. Although the coffee experience is often highly individualistic, the characteristic aroma, acidity, and flavor of a coffee are attributed to the inorganic anions, organic acids, chlorogenic acid, and monosaccharides content. Organic acids—such as malic, quinic, acetic, formic, and citric—provide much of the acidity associated with coffee.

In this application brief, a Dionex ICS-5000 capillary RFIC system with the Thermo Scientific Dionex IC Cube module, a Thermo Scientific Dionex AS-AP Autosampler, and Thermo Scientific™ Dionex™ Chromeleon™ Chromatography Data System (CDS) software were used for all analyses.

Conditions	
Column:	Dionex IonSwift MAX-100 guard, MAX-100 capillary, 0.25 × 250 mm
Eluent Source:	Dionex EGC-KOH capillary
Gradient:	0.1 mM KOH from –10 to 4 min, 0.1–2 mM from 4 to 6 min, 2–15 mM from 6 to 12 min, 15–35 mM from 12 to 16 min, 65 mM from 17 to 30 min
Flow Rate:	12 µL/min
Inj. Volume:	0.4 µL
Column Temp.:	30 °C
Detection:	Suppressed conductivity, Dionex ACES Anion Capillary Electrolytic Suppressor,recycle mode
Sample Prep.:	1:50 dilution



Separation of anions in a brewed caffeinated coffee sample by capillary IC on a Dionex IonSwift MAX-100 column.

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Download Application Brief 135: Determination of Anions and Organic Acids in Brewed Coffee Samples Using Capillary IC

Technology Overview

- Reagent-Free Ion Chromatography
- High-Pressure Ion Chromatography 4 µm Particle Columns
  Capillary Ion Chromatography
- High-Performance Anion-Exchange Chromatography with
  Pulsed Amperometric Detection
- 2-Dimensional Ion Chromatogaphy
- Chromatography Data Systems
- Ion Chromatography and RFIC Systems

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Eluent Generation

RFIC-EG systems have redefined IC by making it possible to just add water to operate an IC system. These systems allow for a simpler and more reliable way to help deliver superior results while simultaneously saving time and labor. Eluent generation allows the automatic production of high-purity IC eluents. This is made possible through precise control of the electric current applied to the electrolysis of water to generate hydroxide and hydronium ions. Eluent generation eliminates the need to manually prepare eluents from concentrated acids and bases. The only routine reagent needed is deionized water. Furthermore, because the instrument pump seals and pistons only come in contact with deionized water, overall pump maintenance is significantly reduced. With eluent generation, a pair of electrodes is positioned with an ion exchange membrane separating them; when a current is applied to the electrodes, electrolysis of water generates hydroxide at the cathode and hydronium at the anode. The ion-exchange membrane prevents the species from recombining into water, and allows a counterion from the Eluent Generation Cartridge to migrate across the membrane to form the eluent. The eluent concentration is varied by changing the applied current to generate eluent within a given range 0–100 mM or 0–200 mM (capillary IC). This entire process can be done without the use of extra pumps, fittings, valves or any moving parts.

High-Pressure IC, 4 µm Columns, Capillary IC

High-Pressure Ion Chromatography

HPIC systems redefine the way ion chromatography is performed due to their continuous operation up to 5000 psi when configured as an RFIC system. High backpressure tolerance lets you increase flow rates to maximize your throughput while still benefiting from the advantages of electrolytic eluent generation and suppression. This feature allows the use of new high-efficiency 4 µm particle-size columns which produce fast run times using 150 mm long columns and high resolution using 250 mm long columns.

4 µm Particle Columns

Chromatographic separations using packed columns benefit from a high number of theoretical plates per column. The number of theoretical plates can be increased by packing smaller particles into the columns. Typically ion chromatography columns use resin particles ranging from 7–9 µm in diameter. Recent developments in resin technology have allowed the use of 4 µm resin particles in ion exchange columns. The benefits of columns packed with smaller particles include more efficient peaks, better resolution, faster run times, easier integration, and more reliable results.

Capillary Ion Chromatography

Capillary IC takes performance to a whole new level while saving time and resources. Capillary IC systems use columns with internal diameters of 0.4 mm and typical flow rates of 10 µL/min. At this rate, only 15 mL of water a day (5.2 L a year) is consumed allowing these systems to be left always on so that they are always ready to run samples.

The waste produced by a capillary IC system is dramatically reduced, compared to that of a system using 4 or 2 mm i.d. columns, which decreases disposal costs. When operated as a RFIC system, the eluent generation cartridge lasts for 18 months under continuous operation. Using eluent generation, only water flows through the pumps which greatly extends the life of seals and decreases maintenance costs.

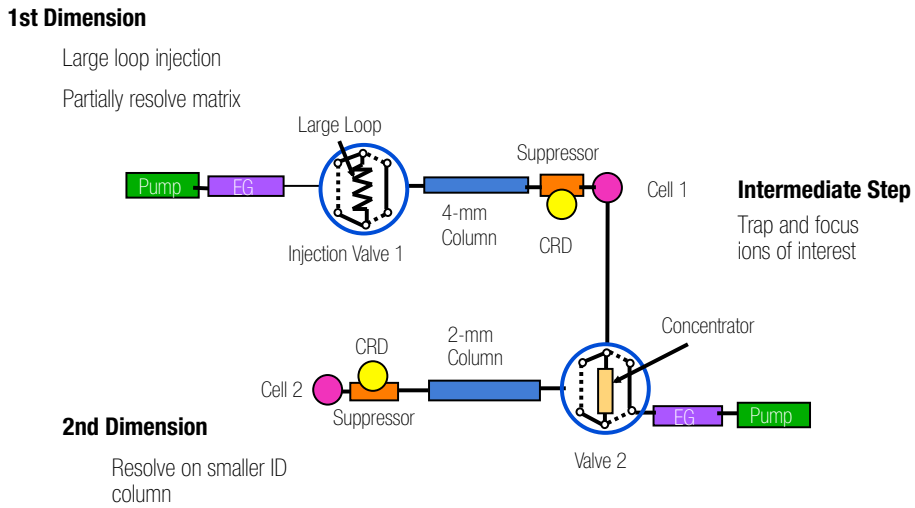
High-Performance Anion-Exchange Chromatography with Pulsed Amperometric Detection (HPAE-PAD) detects carbohydrates by measuring the electrical current generated by their oxidation at the surface of a gold electrode. Pulsed amperometry permits detection of carbohydrates with excellent signal-to-noise ratios and sensitivities down to sub-picomole levels without requiring derivatization. PAD is the application of defined potentials to a working electrode over a specific time period. This is known as a waveform. The oxidation of a carbohydrate is performed at a specific potential and results in the loss of an electron, which results in a current flow which can then be measured at that potential, ensuring selective and sensitive detection. After oxidation, other potentials are applied to remove the bound analyte and renew the electrode surface.

Example HPAE-PAD applications:

- Sugar alcohol determination in fruit juices
- Sialic acids in infant formula
- Carbohydrates and glycols in fermentation broths and other cultures

2-Dimensional Ion Chromatography

Adding another dimension to a chromatographic system allows components that might interfere with analysis to be shunted to waste while analytes of interest are retained (matrix elimination), which results in improved selectivity and signal enhancement. A conventional ion chromatography system is equipped with a single injection valve, and adding valves for various applications such as two-dimensional separations and sample preparation applications is cumbersome. However, modular designs, such as that of the Dionex ICS-5000⁺ system, greatly facilitates reconfiguration of the system for applications such as two-dimensional ion chromatography (2-D IC). The overall strategy for matrix removal and signal enhancement is shown graphically in the figure below. An example of the use of 2-D IC is the determination of bromate in mineral waters.



Digram of a 2-D IC configuration.

Learn more about 2-D IC at: www.thermoscientific.com/2dic

Chromatography Data Systems

Software is more than just an essential component of a modern chromatography data system – it's often the most important factor in getting the desired results. Whether your needs are basic or complex – whether you use instruments from Thermo Fisher Scientific, or from other manufacturers, or both – there's a Thermo Scientific™ Dionex™ Chromeleon™ Chromatography Data System (CDS) software solution that's right for you.

An unparalleled suite of tools for rapid run start and automated, fast data processing:

- Download an eWorkflow™ for immediate execution of a complete IC method from a single online location, the AppsLab Library of Analytical Applications
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- SmartPeaks™ Integration Assistant for easy integration of unresolved peaks
- Immediate visualization of your results and modifications with dynamic interactive data processing

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