# Analysis of aluminum in beverages using the Agilent 4100 Microwave Plasma-Atomic Emission Spectrometer (MP-AES)

## Application note

Food Testing


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## Abstract

Aluminum present in a beverages can affect the taste. This application note describes the determination of aluminum in beverages using an Agilent 4100 MP-AES. Beverages contain a variety of matrix constituents, including salt, sugar, and alcohol. A study was performed to determine how these matrix constituents affect aluminum measurements, and what could be done to reduce such effects. It was determined that sufficient analysis is possible so long as the matrix concentration and alcohol concentration are known to some extent.

## Introduction

At present, absorption spectrophotometry, atomic absorption spectrophotometry and inductively coupled plasma-atomic emission spectroscopy have been adopted for performing elemental analyses of food. Aluminum content in food and beverages is restricted by municipal water supply quality standards to a maximum of 0.2 mg/L on the basis of the Japanese Waterworks Law. When flame atomic absorption spectroscopy (FAAS) is utilized, low sensitivity for aluminum and high matrix constituents in the beverage can cause problems with burners getting clogged. This study was conducted to see if an MP-AES, instead of an FAAS, could be used for beverage analysis.

## Experimental

### Instrumentation

The measurements were performed on an Agilent 4100 MP-AES. The 4100 MP-AES is a compact bench-top spectrometer that generates a robust, magnetically-excited nitrogen plasma.

A 2.45-GHz air-cooled magnetron is used to generate a magnetic field around a torch. The skin effect of that magnetic field causes plasma to form in the shape of a donut, just as with inductively coupled plasma, and it becomes possible to introduce liquid samples at a steady rate (see Figure 1). The nitrogen used to generate the plasma can be supplied via a simple air compressor and the Agilent 4107 Nitrogen Generator.

A clear advantage of in-house gas generation is the reduced costs of operation and maintenance compared to conventional gas resupply.

The sample introduction system used for this application consisted of a standard torch, a single pass cyclonic spray chamber and a glass concentric nebulizer.

Table 1 lists the instrument operating conditions.

**Table 1.** Agilent 4100 MP-AES operating conditions

| Parameter | Value |
|---|---|
| Microwave power | 1.0 kW |
| Pump speed | 15 rpm |
| Integration time | 3 seconds |

### Standard and Sample Preparation

Samples included:

- Barley tea
- Green tea
- Black tea
- Coffee
- Cola
- Sports drink
- Beer
- Shochu highball

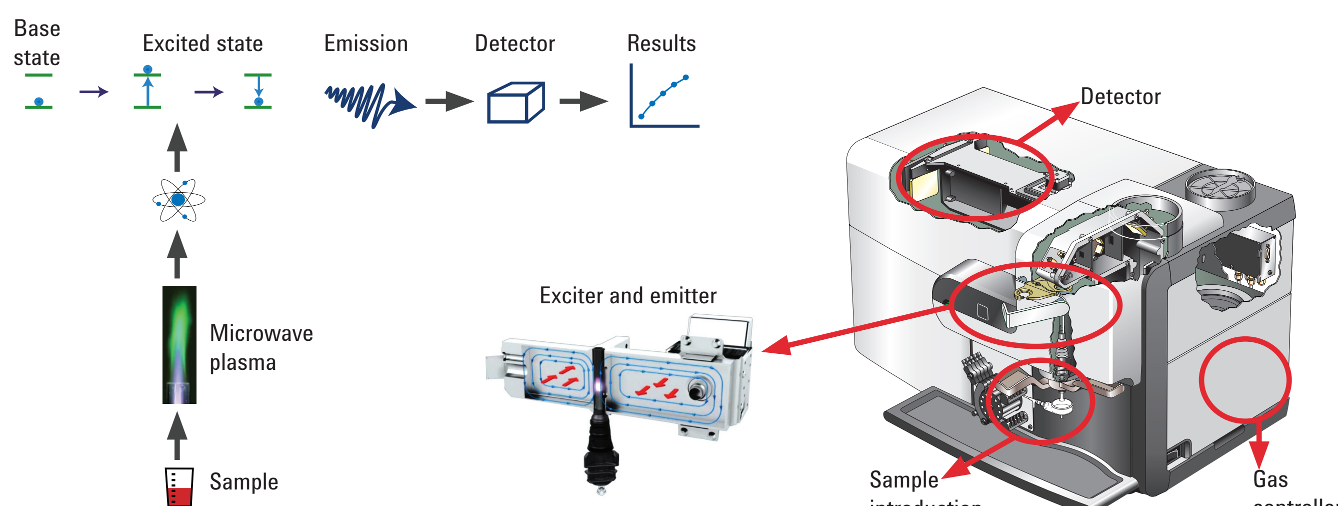


**Figure 1.** Schematic and basic principles behind the Agilent 4100 MP-AES

## Results

### Quantitative lower limits and stability

The quantitative lower limits and stability in aqueous solutions and in ethanol were measured. A 0.1% nitric acid solution and ethanol diluted at 0.2 mg/L was prepared using standard solutions.The quantitative lower limit was assumed to be a concentration ten times the standard deviation (σ) obtained from repeatedly measuring the blank ten times. The stability was calculated by repeatedly measuring each of the 0.2 mg/L solution ten times (see Table 2).

**Table 2.** Method detection limits (MDL) by MP-AES

| Aluminum | Limit of quantification (µg/L) | Stability at 0.2 mg/L (%RSD) |
|---|---|---|
| Aqueous solution | 1.9 | 1.4 |
| Ethanol (100%) | 7.9 | 0.7 |

The results for limit of quantification and stability confirm that microwave plasma atomic emission spectroscopy is sufficiently applicable for the analysis of aluminum in beverages.

### The effects of sugar

With the emission intensity of aluminum at 0.2 mg/L with a sugar concentration of 0 g/100 mL given a value of 1, the effects of varying the sugar concentration between 0 and 50 g/100 mL were measured. The sugar concentrations of the samples were: approx. 2–5 g/100 mL for black tea (with sugar), and 11 g/100 mL for cola (see Figure 2).

The measurements show that sugar concentrations up to approximately 10 g/100 mL do not have a significant effect. Additional standards and matrix matching are needed for concentrations above 10 g/100 mL. The samples examined had a sugar concentration of about 11 g/100 mL, so the analysis was performed using the absolute calibration method.

### The effects of ethanol

An additional study was conducted to see if the 4100 MP-AES could be used to determine aluminum content in alcoholic beverages sold in aluminum cans. Subjecting alcohol to plasma produced a relatively large amount of carbon in relation to the concentration of alcohol. Carbon can cause the torch injector to become blocked. To prevent this, air was mixed with the support gas before subjecting it to the plasma.

With the emission intensity of aluminum in a 0.2 mg/L solution set to 1, the effects of varying the ethanol content from 0 to 10% in the solution were examined (see Figure 3).

There were no significant variations either with or without air at ethanol concentrations of about 5%, but emission intensity declined at concentrations above 5% with no air added. Beer is approximately 5% alcohol, while some shochu highballs are higher, at about 8%. For that reason, the sample analysis was performed with air added.

Aluminum was added to each sample, and the results of the recovery tests are given in Table 3.

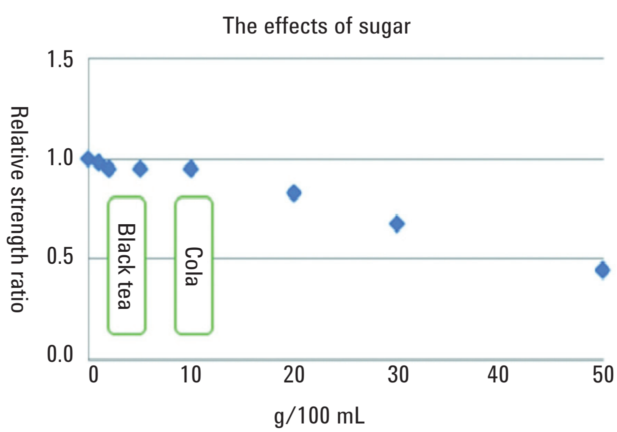


**Figure 2.** Variation in emission intensity due to differences in sugar concentration

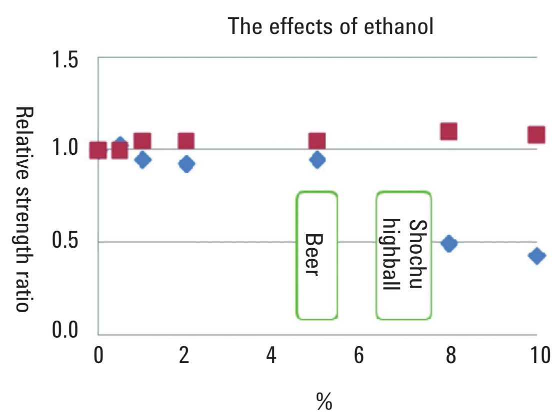


**Figure 3.** Variation in emission intensity due to differences in ethanol concentration, with and without adding air.
Red squares = with air, blue diamonds = without air

**Table 3.** Aluminum addition recovery tests

| Al | Unspiked (mg/L) | 0.2 mg/L added (mg/L) | Recovery rate (%) |
|---|---|---|---|
| Barley tea | 0.00 | 0.22 | 110 |
| Coffee | 0.01 | 0.23 | 109 |
| Sports drink | 0.01 | 0.22 | 105 |
| Cola | 0.05 | 0.24 | 96 |
| Beer | 0.04 | 0.23 | 96 |
| Shochu highball | 0.01 | 0.22 | 105 |
| **Al** | **Unspiked (mg/L)** | **1.0 mg/L added (mg/L)** | **Recovery rate (%)** |
| Green tea | 1.14 | 2.12 | 99 |
| Black tea | 2.45 | 3.38 | 98 |

## Conclusion

This study has shown that the limit of quantification for aluminum is 1.9 µg/L in aqueous solutions and 7.9 µg/L in ethanol, which adequately meets municipal water supply quality standards as stated in the Japanese Waterworks Law. Favorable results with regard to stability were also obtained. The results of the examination for the effects of beverage matrices (sugar and alcohol) showed that direct measurements without matrix matching can be done for concentrations of about 10 g/100 mL of sugar in beverages, and that the Agilent 4100 MP-AES can also easily and rapidly analyze samples with differing alcohol concentrations if air is mixed in. Thus, it has been demonstrated that the MP-AES has low running costs, is easy to operate, and can perform analyses of aluminum in beverages.

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