Evaluation of Sample Preparation methods for the Determination of Cereulide in Infant Formula Using LC-MS/MS

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1. Introduction

Cereulide is a heat-stable emetic toxin produced by Bacillus cereus. Since even the ingestion of small amounts raises concerns about health effects, appropriate management of food is required. In particular, infants may experience vomiting and diarrhea from ingesting very small amounts. Therefore, the safety requirements for infant formula are extremely high, necessitating analytical methods capable of reliable detection and quantification even at low concentration ranges.

The European Food Safety Authority (EFSA) proposed an acute reference dose (ARfD) of 0.014 µg/kg body weight for infants in a rapid risk assessment, indicating that cereulide concentrations exceeding 0.054 µg/L in reconstituted infant formula may surpass safety thresholds1). However, since infant formula is a complex matrix rich in lipids and proteins, selecting an appropriate sample preparation method is crucial.

This Application News introduces an example of analyzing cereulide in infant formula using triple quadrupole LC-MS/MS, comparing sample preparation methods based on ISO 18465 and the QuEChERS approach. Spike-and-recovery tests yielded good recoveries for both methods, but the QuEChERS approach demonstrated a higher recovery rate.

2. Methods

2.1. Sample Preparation

A commercially available infant formula, reconstituted according to the manufacturer's instructions, was used as the sample.

2.2. Method Based on ISO 18465

First, 2.5 mL of the sample was placed in a 50 mL tube and mixed with 30 mL of acetonitrile. After shaking for 1 hour on a shaker, the mixture was centrifuged at 3,000 rpm for 5 minutes. The collected supernatant was filtered using a TORAST Disc (hydrophilic PTFE, 13 mm diameter, 0.45 µm pore size, P/N: GLCTD-HPTFE1345) to prepare the sample for LC-MS/MS analysis. The sample preparation flow is shown in Fig. 1 (a).

2.3. QuEChERS Method

First, 2 mL of the sample was placed in a 50 mL tube, and 8 mL of water, 150 µL of formic acid, and 10 mL of acetonitrile were added, followed by shaking for 10 seconds. One extraction salt packet (Supel QuE, P/N: 55295-U) was added, and the tube was immediately shaken vigorously by hand for 10 seconds. After shaking for 5 minutes on a shaker, the mixture was centrifuged at 3,000 rpm for 5 minutes. The collected supernatant was used as the sample for LC-MS/MS analysis. The sample preparation flow is shown in Fig. 1 (b).

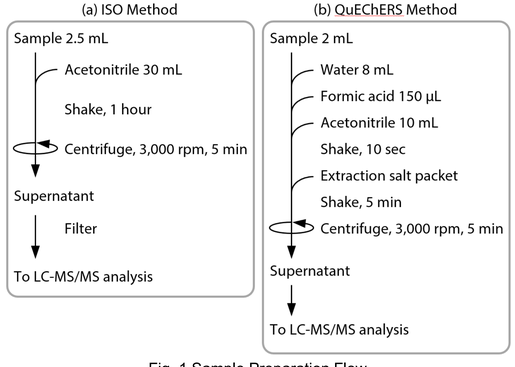

Fig. 1 Sample Preparation Flow

Table 1 LC-MS/MS Analytical Conditions

HPLC conditions (Nexera X3)		
Column	:	Shim-pack Scepter C18-120*1 (50 mm x 2.1 mm I.D., 1.9 µm)
Mobile phase A	:	10 mM ammonium formate / 0.1% formic acid / water
Mobile phase B	:	Acetonitrile
Flow rate	:	0.4 mL/min
Gradient program	:	B conc. 80-95% (0-6 min) → 95% (6-10 min) → 80% (10.01-13 min) The flow was introduced into the mass spectrometer between 3 to 8 min using a flow switching valve.
Column temp.	:	40˚C
Injection volume	:	5 µL
MS conditions (LCMS-8060RX)		
Ionization	:	ESI, Positive mode
Mode	:	MRM
Interface voltage	:	+1 kV
Focus voltage	:	+2 kV
Nebulizing gas flow	:	2.0 L/min
Drying gas flow	:	5.0 L/min
Heating gas flow	:	15.0 L/min
Interface temp.	:	300˚C
DL temp.	:	300˚C
Heat Block temp.	:	500˚C
Probe position	:	+1 mm

*1 P/N: 227-31012-03

Fig. 2 LCMS-8060RX and Nexera X3

Table 2 MRM Transitions

Quantifier Ion	Qualifier Ion
1170.70>314.15	1170.70>172.05 1170.70>357.30 1170.70>499.10

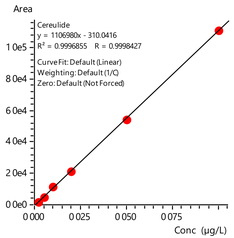

Fig. 3 Calibration Curve Using Cereulide Standard

2.4. Analytical Conditions

Quantitative analysis was performed using a triple quadrupole mass spectrometer LCMS-8060RX coupled with a Nexera™ X3 UHPLC system (Fig. 2). A Shim-pack Scepter™ was used as the analytical column, and the analysis was carried out with a 13-minute method including column washing and equilibration. The analytical conditions are shown in Table 1, and the MRM conditions in Table 2. The transitions recommended in ISO 18465 were used for quantification.

3. Results

Two sample preparation methods, an ISO 18465-based method and a QuEChERS method, were compared for the quantification of cereulide in reconstituted infant formula.

To evaluate the validity of both methods, spike-and-recovery tests were conducted using each method. For the spiked samples, a cereulide standard was added to achieve a concentration of 0.054 µg/L in the reconstituted infant formula, based on the risk assessment criteria proposed by EFSA. After adding the standard, the samples were prepared using each method, and analysis was conducted using triple quadrupole LC-MS/MS.

Quantification was carried out by the external standard method, and a calibration curve was constructed in the range of 0.002 to 0.1 µg/L (Fig. 3). The accuracy of all calibration points ranged from 98.1% to 105.1%.

Table 3 Comparison of Spike-and-Recovery Test Results using ISO and QuEChERS Methods

		ISO Method	QuEChERS Method
Pre-spiked sample	Recovery (n=3)	90.6	100.1
	%RSD	9.7	2.3
Post-spiked sample	Recovery (n=1)	109.3	108.7

The final concentration of the prepared sample (in the vial) was 0.0045 µg/L for the ISO 18465-based method and 0.0108 µg/L for the QuEChERS method. Samples were prepared in triplicate (n = 3) for each method to confirm reproducibility. The results are shown in Table 3. The recovery rates were 90.6% for the ISO 18465-based method and 100.1% for the QuEChERS method. The reproducibility (%RSD) values were 9.7% and 2.3%, respectively. Mass chromatograms of cereulide in the standard solution and spiked samples are shown in Fig. 3.

In addition, the matrix effect on the ionization of cereulide was evaluated. The recovery rates of post-spiked samples—prepared by adding the standard to unspiked sample extracts just before LC-MS/MS analysis—were determined. As a result, the recovery rates for both sample preparation methods ranged from 108.7% to 109.3% (Table 3).

4. Conclusions

- ✓ A triple quadrupole LC-MS/MS system enabled highly sensitive and accurate quantification of cereulide in reconstituted infant formula.
- ✓ Both the ISO 18465-based method and the QuEChERS method showed good recovery performance, with recovery rates ranging from 90.6% to 100.1%.
- ✓ These methods allowed accurate quantification of cereulide at 0.054 µg/L, which corresponds to the safety threshold proposed by EFSA.

<References>

1) European Food Safety Authority (EFSA), Eskes C, et al. Rapid risk assessment on acute reference dose (ARfD) of cereulide in infants and information on acute consumption of infant formulae. EFSA Journal, 2026. https://doi.org/10.2903/j.efsa.2026.9941
2) ISO 18465. Microbiology of the food chain - Quantitative determination of emetic toxin (cereulide) using LC-MS/MS. 2017.