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# Robust and Fast Analysis of Tobacco-Specific Nitrosamines by LC-MS/MS

## **INTRODUCTION**

Tobacco-specific nitrosamines (TSNA) are a group of carcinogens found only in tobacco products. They are formed from nicotine and related alkaloids during the production and processing of tobacco and tobacco products.<sup>1</sup> Due to their carcinogenic properties, efforts have been made to reduce TSNA levels in tobacco products. The desired goal of this investigation is to develop a sensitive, high-throughput method to monitor TSNA levels in tobacco and tobacco products. This study focuses on N<sup>1</sup>-nitrosornicotine (NNN), N<sup>1</sup>-nitrosoanatabine (NAT), N-nitrosoanabasine (NAB), and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK).

Conventional methods for TSNA analysis are based on gas chromatography with a thermal energy analyzer (GC-TEA)<sup>2,3</sup>, or high-performance liquid chromatography (HPLC) with various detection techniques such as UV and mass spectrometry (MS).<sup>4-6</sup>

This application note (AN) describes a robust and fast LC-MS/MS method developed to analyze the four TSNA in tobacco cigarettes after a simple sample preparation of ammonium acetate liquid extraction and filtration. The chromatographic separation of the four TSNA was achieved within 3.5 min and these analytes were detected with great sensitivity and selectivity by tandem mass spectrometry using Selected Reaction Monitoring (SRM) detection. This method has been evaluated with respect to linearity, detection limits, precision, and accuracy. The ruggedness of the methodology was proven with more than 1000 replicate injections.

## **EXPERIMENTAL**

### **Instrumentation**

#### **HPLC**

P680 dual ternary pump  
ASI-100 autosampler  
TCC-100 thermostatted column compartment  
UVD340U detector

#### **Mass Spectrometer**

TSQ Quantum Access™ triple quadrupole mass spectrometer with heated electrospray ionization (HESI) interface.

#### **Software**

Xcalibur® 2.0

Dionex DCMS<sup>Link</sup>™ for Xcalibur (version 2.0)\*

\* DCMS<sup>Link</sup> is a Chromeleon®-based software module providing the interface for controlling a wide range of Dionex chromatography instruments from different mass spectrometer software platforms.

## **CONDITIONS**

### **Chromatographic Conditions**

Analytical Column: Acclaim® RSLC PA2  
(5.0 × 2.1 mm, 2.2 μm)  
Column Temperature: 60 °C  
Injection Volume: 10 μL  
Mobile Phase: 10% CH<sub>3</sub>CN in buffer  
(1 mM NH<sub>4</sub>OAc, pH adjusted to pH 8.0 by NH<sub>4</sub>OH)  
Flow Rate: 0.50 mL/min  
Detection: UV at 230 nm  
TSQ Quantum Access SRM

## Mass Spectrometric Conditions

Needle Voltage: 2000 V  
Vaporizer Temp.: 350 °C  
Sheath Gas: 60 (arbitrary unit)  
Auxiliary Gas: 50 (arbitrary unit)  
Ion Sweep Gas: 2 (arbitrary unit)  
Collision Gas Pressure: 1.5 mTorr  
Capillary Temp.: 350 °C

## SRM Transitions:

NNN	178.1 → 148.1 <i>m/z</i>	11 V
	178.1 → 120.1 <i>m/z</i>	18 V
NNK	208.1 → 122.1 <i>m/z</i>	11 V
	208.1 → 79.2 <i>m/z</i>	38 V
NNK-d <sub>4</sub>	212.1 → 126.1 <i>m/z</i>	11 V
	212.1 → 83.2 <i>m/z</i>	38 V
NAT	190.1 → 160.1 <i>m/z</i>	10 V
	190.1 → 79.2 <i>m/z</i>	5 V
NAB	192.1 → 162.1 <i>m/z</i>	10 V
	192.1 → 133.1 <i>m/z</i>	24 V

The 1st SRM transition of each compound is used for quantification and the 2nd SRM transition is used for confirmation.

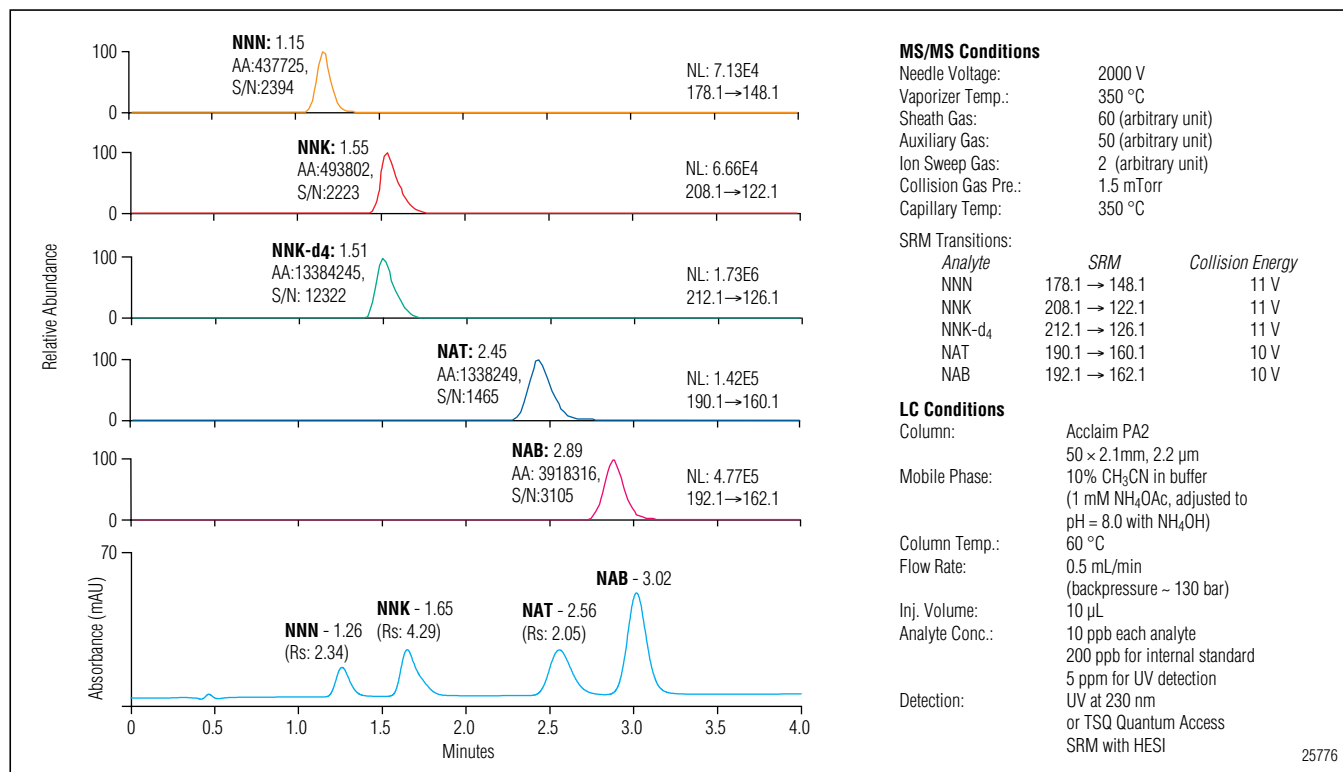
## SAMPLE PREPARATION

Tobacco cuts from five brands of cigarettes were weighed to 0.25 grams into 20 mL glass vials, and extracted with 10 mL of 100 mM ammonium acetate solution. The vials were placed on a swirl table and agitated for 30 min. The extracts were filtered through 0.25 µm membrane syringe filters. A 1.0 mL aliquot of each extract was then spiked with 10 µL internal standard (IStd, NNK-d<sub>4</sub>) in preparation for LC-MS/MS analysis.

## RESULTS AND DISCUSSION

### Chromatography

As shown in Figure 1, the four TSNAs are retained and completely resolved within 3.5 min, with the minimum of the retention factors ( $K'_{NNN}$ ) greater than 4 and minimum resolution ( $R_{s,NAT}$ ) greater than 2.0. These demonstrated retention factors ensure analytes of interest are chromatographically separated from early eluted compounds that can suppress ionization. The total chromatographic resolution minimizes the possibility of ionization suppression and eliminates cross-contamination of SRM transitions between main analytes.



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Figure 1. Comparison of SRM and UV chromatograms of TSNAs on the Acclaim RSLC PA2 column.

## Mass Spectrometry

Tandem mass spectrometry provides specific and sensitive detection. The SRM chromatograms in Figure 1 show that quantification can be performed with a high level of confidence even at low concentration (10 ng/mL, 0.1 ng injected amount). The use of SRM detection enabled simplification of sample preparation and a significant reduction in total process time.

## Method Performance

Internal standard quantification and calibration were performed using isotope labeled NNK- $d_4$  (IStd). Calibration standards were prepared at 8 levels from 2 ng/mL to 1000 ng/mL. Triplicate injections were performed to generate calibration curves, and a coefficient of determination ( $r^2$ ) greater than 0.99 was achieved for each analyte.  $1/X$  weighting provided best quantification for low concentration samples. Excellent linearity was achieved for NNK with  $r^2 = 0.9998$ , suggesting that the use of isotope-labeled analogs as internal standards could provide better quantification accuracy and precision. The calibration curve is shown in Figure 2.

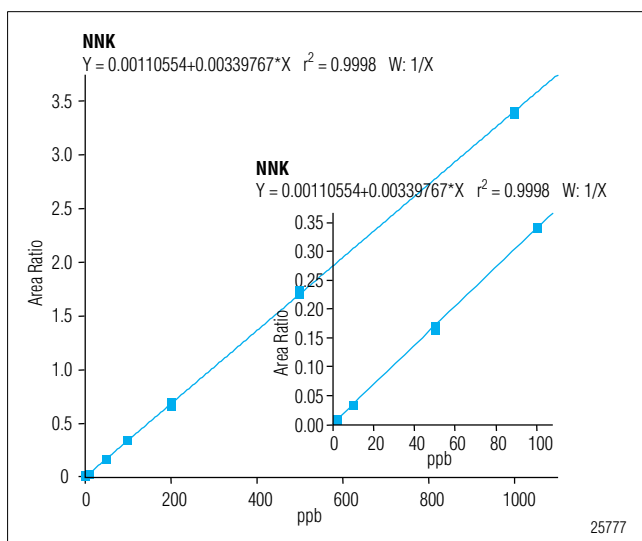


Figure 2. Calibration curve of NNK using NNK- $d_4$  as internal standard.

Method detection limits (MDLs) were statistically calculated using the equation  $MDL = S \times t_{(99\%, n=7)}$  where  $S$  is the standard deviation, and  $t$  is student's  $t$  at 99% confidence interval. Seven replicate injections of a standard solution at 2 ng/mL were performed, and used for MDL calculations. The MDLs for TSNA range from 0.22 ng/mL (NAB) to 0.38 ng/mL (NNK).

Precision and accuracy were evaluated at 10 ng/mL and 100 ng/mL. Seven replicate injections of calibration standards at both levels were performed, and quantification was calculated based on the calibration curves. The results in Table 1 show that the quantification of NNK was very accurate and precise ( $< 4\%$  difference,  $< 4.5\%$  RSD) at both low (10 ng/mL) and medium levels (100 ng/mL). However, significant inaccuracy was observed for NAB and NAT at the low level, showing 54.2% and 36.6% quantification differences respectively. This observation suggests better quantification accuracy may be achieved using an isotope labeled internal standard for each analyte for low-level TSNA analysis, for example, analyzing TSNA in biological matrices.

Table 1. Precision and Accuracy

	10 ng/mL		100 ng/mL	
	Accuracy (%)	% RSD	Accuracy (%)	% RSD
NAB	154.2	2.74	103.7	1.49
NAT	136.6	4.69	100.7	1.77
NNK	103.9	4.38	100.9	1.88
NNN	95.3	3.56	94.4	1.56

## Method Ruggedness

Since the analytical column was running under the very harsh conditions of high temperature and high pH mobile phase, method ruggedness was evaluated by repeated injections of standard solutions and tobacco extracts. As shown in Figure 3, chromatographic retention and resolution were well-maintained after more than 1000 injections. The column was cleaned with 50/50 CH<sub>3</sub>CN/H<sub>2</sub>O before injection 250 and a new inlet frit was installed before injection 1003. (The use of an in-line filter is highly recommended to prevent column clogging.)

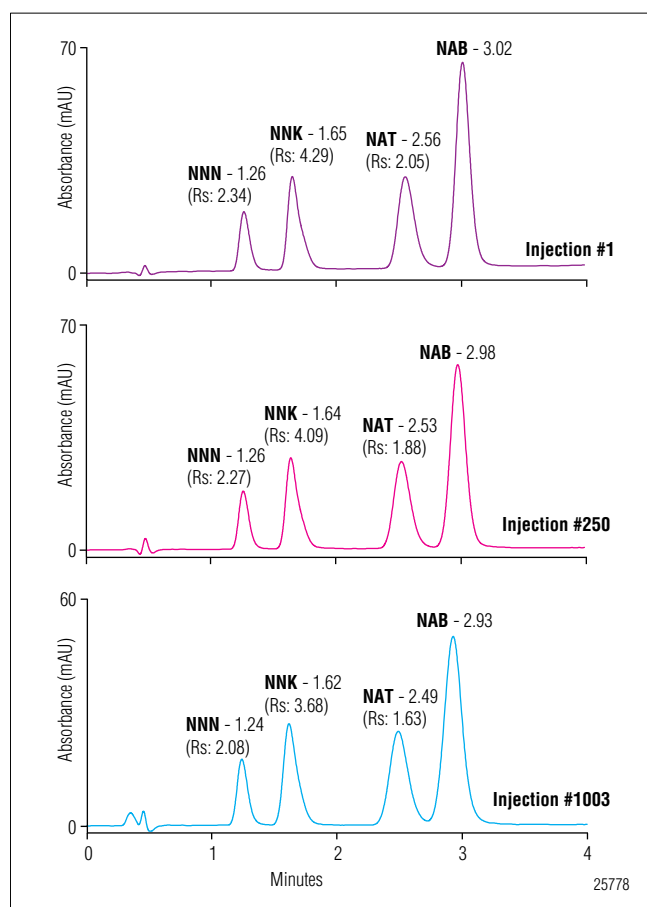


Figure 3. Ruggedness of the Acclaim RSLC PA2 column.

## Determination of TSNA in Tobacco Cigarettes

Five brands of tobacco cigarettes were purchased from a local convenience store. Tobacco cuts from each brand of cigarettes were prepared (n = 3) following the procedure described previously. The results are shown in Table 2. The TSNA contents are significantly different between brands A and B and brands C, D, and E. The differences in TSNA content could be related to differences in the tobacco blended in each brand, such as type, origin, age of the tobacco, curing method, and storage conditions. The comparison of brands A and B (regular and light varieties of a premium US brand of cigarettes) shows no difference for TSNA contents except for a change in the amount of NAB. See Figure 4 for SRM chromatograms of TSNA from brand A cigarette.

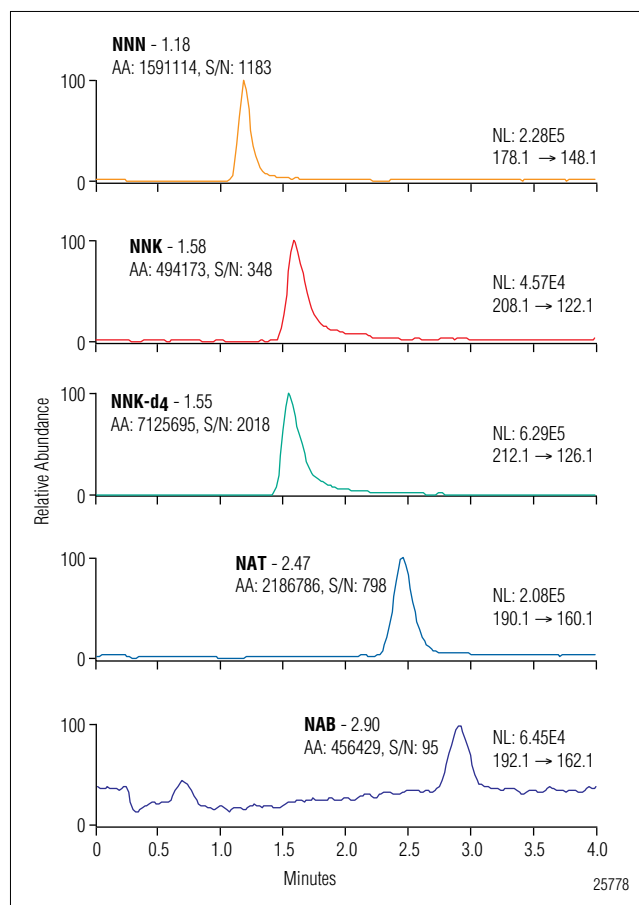


Figure 4. SRM chromatograms of TSNA from brand A cigarette.

**Table 2. TSNAs in Tobacco Cigarettes\***

	NAB	NAT	NNK	NNN	Note
<b>Brand A</b>	5.3	1145.1	676.5	2221.1	US brand, regular
<b>Brand B</b>	42.1	1218.1	696.0	2472.5	US brand, lights
<b>Brand C</b>	40.1	160.8	225.2	213.0	US brand, all natural
<b>Brand D</b>	21.2	103.9	70.2	155.4	International brand
<b>Brand E</b>	32.7	78.2	87.8	114.3	Asian brand

\*Amounts shown in Table 2 are ng/g tobacco cuts.

## CONCLUSION

A rugged and ultrafast method for TSNA analysis was developed using HPLC-MS/MS on an Acclaim RSLC PA2 column. Four TSNAs were chromatographically retained and resolved within 3.5 min. Tandem mass spectrometry ensured selectivity and sensitivity. The use of isotope-labeled internal standards for each analyte may improve the quantification accuracy, as was observed for NNK in this study. The ruggedness of the method was shown by more than 1000 injections of standards and tobacco extracts. The applicability of the method for the determination of TSNAs in tobacco cuts from five brands of cigarettes was demonstrated.

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