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N-Nitrosodimethylamine Concentrations in Domestic and Imported Beer in Korea

– Research Note –

Hyun-Joo Ahn, Jae-Hyun Kim, Cheorun Jo, Myung-Chul Kim*, Jin-Hwan Hong* and Myung-Woo Byun†

Team for Radiation Food Science & Biotechnology, Korea Atomic Energy Research Institute, Daejeon 305-353, Korea
**Department of Food Evaluation, Korea Food and Drug Administration, Seoul 122-704, Korea*

Abstract

***N*-Nitrosodimethylamine (NDMA) was determined in both domestic Korean and imported beers, from the Netherlands, USA, Japan, Belgium and Germany. Among the 8 kinds of Korean beers, 4 were contaminated with NDMA, and 4 were not. The average concentration of NDMA detected in Korean beers was 0.78 μg/kg and the maximum NDMA concentration was 5.73 μg/kg. NDMA was only detected in one imported beer, which had a concentration of 5.29 μg/kg. Assuming an average concentration of 0.78 μg/kg NDMA in Korean domestic beer, the average daily intake of NDMA through domestic beer consumption by a typical Korean is approximately 0.58 μg/person/day.**

Key words: *N*-nitrosodimethylamine, domestic, imported, beer

INTRODUCTION

Volatile *N*-nitrosamine formation in foods occurs due to addition of nitrite, smoking, drying with combustible gas, salting, pickling, fugal contamination or food contact with contaminated materials. *N*-Nitrosamines, such as *N*-nitrosodimethylamine, reportedly induce cancer in human organs including the tongue, esophagus, liver, lungs, kidney, bladder, and spleen depending on the type and concentration of *N*-nitrosamines. The mechanism of carcinogenesis by *N*-nitrosamine involves the substitution of DNA nucleotide sequences after *N*-nitrosamine is activated in endoplasmic reticulum by cytochrome p-450E and goes through several steps (1). Among the several foodstuffs having *N*-nitrosamine problem, *N*-nitrosodimethylamine (NDMA) in beer had been issued in the past 20 years in various countries (2,3). Havery et al. (4) reported that traces of NDMA and *N*-nitrosopyrrolidine (NPYR) had been detected in beer in rare instances, but that such occurrences are very uncommon.

The details of these findings have been reviewed by many investigators (5-8). Sen et al. (9) summarized the main findings as follows: (a) malt was found to be the main source of NDMA contamination in beer, and it was shown to be formed during direct drying of malt using hot flue gasses-a practice that was common prior to 1980; (b) burning of sulfur with the fuel or the introduction of SO_2 gas into the hot flue gas, especially during the first 8~10 hour of malt kilning, greatly reduced NDMA formation; and (c) malt dried by indirect heating where it did not come in physical contact with the hot flue gas, or that dried by electric heating, formed the least amount of NDMA.

Recent studies in various countries including Canada (9), Brazil and U.S. (10), and Spain (11) showed that NDMA concentrations in beers were greatly reduced or not detected; accordingly, there were no need for further mention and discussion. In Korea, data in the literature on NDMA concentrations in beers are very limited except for some report by Sung et al. (12) in 1996. Sung et al. (12) surveyed relatively high concentrations of NDMA in domestic beer compared to other countries. Afterwards, no research related to NDMA in Korean domestic and imported beers has been found. Therefore, continued monitoring of NDMA concentrations in Korean beer seems necessary to ascertain the safety of domestic beer and encourage improvements in quality and safety standards in the Korean brewery industry. The objective of the present study was to provide current information on NDMA concentrations in domestic and imported beers available in Korean market.

MATERIALS AND METHODS

Sample preparation

Domestic and imported beers, in cans or bottles, were

†Corresponding author. E-mail: mwbyun@kaeri.re.kr
Phone: 82-42-868-8060, Fax: 82-42-868-8043

purchased from retail store in Daejeon. All of the beers manufactured in 2001 were remarked as an alphabet order irrespective of their own brand. The country origins of imported beers were the Netherlands, USA, Japan, Belgium and Germany.

N-Nitrosodimethylamine analysis

The extraction of volatile *N*-nitrosodimethylamine (NDMA) in beers was performed by the method of Raoul et al. (13) with some modifications using Extrelut® NT3 pre-packed glass column (160 mm × 15 mm, Merck, Darmstadt, Germany) with added Extrelut® packing materials (Merck). The *N*-nitrosodipropylamine (1 μg/mL) was used as an internal standard for extraction efficiency. The mean recovery value for the internal standard obtained from all samples was 92.89 ± 7.886%.

NDMA was determined quantitatively by gas chromatography (GC, Model 5890II, Hewlett-Packard Co., Wilmington, DE, USA) coupled to a thermal energy analyzer (TEA, Thermo Electron Model 502B, Waltham, MA, USA). Analyses were carried out with a non-polar SPB-5 fused silica capillary column (30 m × 0.53 mm I.D., Supelco Co., Bellefonte, PA, USA), which was introduced into the ceramic pyrolysis tube by the end of TEA. Helium was used as the carrier gas at a flow rate of 3.5 mL/min. The injection port was set at 220°C and the temperature of the column port was ramped; 50°C for 5 min, increased to 200°C at 5°C/min. The injection volume was 2 μL. Duplicate analyses were performed on all samples. Then, the data was analyzed with SAS program (14).

RESULTS AND DISCUSSION

N-Nitrosodimethylamine concentration

NDMA concentrations in both domestic and imported beers along with their types and sources are shown in Tables 1 and 2, respectively.

Table 1. *N*-Nitrosodimethylamine (NDMA) concentration in domestic beers

Sample	Type of beer	NDMA (μg/kg)
A[1]	Lager (4.5%)[2]	ND[3]
B	Lager (4.5%)	ND
C	Lager (4.2%)	2.86 (1.08 ~ 5.63)[4]
D	Lager (4.2%)	2.54 (0.50 ~ 4.87)
E	Lager (4.5%)	1.90 (0.92 ~ 3.90)
F	Lager (4.1%)	ND
G	Lager (5.0%)	0.96 (0 ~ 1.92)
H	Dark (5.0%)	ND

[1]The domestic beers were remarked irrespective of their own brand.
[2]Alcohol content labelled in beers.
[3]Not detected.
[4]Means (range).

Table 2. *N*-Nitrosodimethylamine (NDMA) concentration in imported beers

Sample	Type of beer	NDMA (μg/kg)
I[1]	Lager (5.0%, the Netherlands)[2]	ND[3]
J	Lager (4.6%, USA)	2.65 (0 ~ 5.29)[4]
K	Lager (5.0%, USA)	ND
L	Lager (5.0%, Japan)	ND
M	Lager (5.0%, Belgium)	ND
N	Dark (5.0%, Germany)	ND

[1]The imported beers were remarked irrespective of their own brand.
[2]Alcohol content and country of origin labelled in beers.
[3]Not detected.
[4]Means (range).

Of the 8 kinds of Korean beers, 4 were contaminated with NDMA, and 4 were not. The average concentration of NDMA detected in Korean beers was 0.78 μg/kg and the maximum NDMA concentration was 5.73 μg/kg. Sung et al. (12) reported that the NDMA concentrations of Korean beers were 0 ~ 7.2 μg/kg in 1996. NDMA was only detected in one imported beer, which had a concentration of 5.29 μg/kg, a similar value to the most contaminated Korean domestic beers. The average daily beer consumption in Korea is 747 g/60 kg person/day (15). Assuming an average concentration of 0.78 μg/kg NDMA in Korean domestic beer, the average daily intake of NDMA from beer by a typical Korean is approximately 0.58 μg/person/day. Gloria et al. (10) estimated the average daily intake of NDMA in the United States to be 0.01 μg/kg. Therefore, the exposure of Koreans to NDMA is much greater than the exposure of people in the United States, partly due to the higher NDMA concentrations in beer and partly because Korean daily beer consumption is higher than in the United States.

During the 1980's, the problem of NDMA contamination surfaced worldwide and, as a result, malt-drying techniques were improved, significantly reducing NDMA in beer. However, since that time no further decline has occurred according to several surveys. Sen et al. (9) reported that the average NDMA level in Canadian beer was significantly reduced to 0.098 μg/kg as compared to average levels of 1.4 μg/kg in 1978. Yin et al. (16) reported that 77% of Chinese beer was contained NDMA with a mean concentration of 2.7 μg/kg. NDMA is the only volatile *N*-nitrosamine normally detected in beer. NDMA is known to induce tumors in a variety of organs, including the liver, lung, kidney, bladder, pancreas, esophagus and tongue, depending on the species, but not in the skin, brain, colon or bone. For example, 20 ppm of *N*-nitrosodimethylamine can induce liver cancer in humans (17). Of the non-volatile *N*-nitroso compounds, *N*-nitrosoproline (NPRO) is the major one detected (18).

Since NPRO is non-carcinogenic to laboratory animals, its presence in beer should not be of much concern.

This study indicated that NDMA levels in Korean domestic beer have decreased slightly in the past 6 years, following the report by Sung et al. (12). However, the concentrations were still higher than those of most other countries. NDMA is a highly carcinogenic contaminant that is present in high concentrations in many Korean beers. The public health risk of NDMA contamination is a compelling reason why continued monitoring and research related to NDMA in beer is needed. The domestic consumption and production of beer continues to increase in Korea. Therefore, additional research is needed to facilitate and encourage improvements in quality and safety standards in the Korean brewery industry.

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