Trends in the Levels of *N*-Nitrosodimethylamine in Canadian and Imported Beers

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N-Nitrosodimethylamine (NDMA) is a potent animal carcinogen that has been detected in trace levels in beers. Studies carried out by the Canadian Health Protection Branch suggest that as a result of improvement in the malt-drying techniques, NDMA levels in both Canadian and imported beers have decreased significantly over the past 10−15 years. Of 162 Canadian beers analyzed during 1982−1989, the average NDMA level was found to be 0.098 ppb (range, <0.1−0.6 ppb) as compared to average levels of 1.4 and 0.7 ppb detected in two earlier (1978 and 1980, respectively) surveys. In the two latest surveys of imported beers carried out during 1991−1992 and 1994, the respective averages were 0.71 ppb (n = 106; range, <0.1−9.1 ppb) and 0.15 ppb (n = 36; range, <0.1−3.2 ppb). The current daily intake of NDMA through beer by an average Canadian is about one-fifteenth of that estimated in 1978−1980.

Keywords: *N-Nitrosodimethylamine; NDMA; beer*

INTRODUCTION

Extensive studies have been carried out during the past 15 years in various countries on the occurrence and formation of *N*-nitrosodimethylamine (NDMA) in beer and ale (International Agency for Research on Cancer, 1977; Spiegelhalder *et al.*, 1979; Sen *et al.*, 1980; Kawabata *et al.*, 1980; Havery *et al.*, 1981; McWeeny, 1983; Oesterdahl, 1988; Frommberger, 1989; Scanlan *et al.*, 1990). There seem to be two main reasons for this world-wide interest on this topic. First, NDMA is a highly potent carcinogen in laboratory animals and has been shown to induce cancer in about 15 species including some primates (Preussmann and Stewart, 1984). Moreover, no species tested has been shown to be resistant to its carcinogenic action. Therefore, it is highly likely that man is also susceptible to its carcinogenic effect although there is no direct evidence of this as yet. For this reason, the presence of NDMA in beer or any other foods or beverages is a matter of concern. Second, initial estimates by German scientists (Spigelhalder *et al.*, 1980) suggested that of all foods or beverages ingested by man, beer contributed the most to the daily intake of NDMA through diet. This also appeared to be the case in many other Western countries (reviewed by Sen, 1986). Although no comparable U.S. and Canadian data were available for the total daily intake of NDMA, earlier estimates indicated that an average resident in these two countries consumed approximately 0.97 and 0.52 μg, respectively, per day through beer (National Academy of Sciences, 1981; Sen *et al.*, 1980). Therefore, it was generally felt that a reduction in the levels of NDMA in beer would go a long way in reducing the intake of this chemical through diets. This explains the reasons for the unusual interest on this topic, especially that shown during the early 1980s.

Since the details of these findings have been reviewed elsewhere (Mangino *et al.*, 1981; Preussmann *et al.*, 1981; Hotchkiss, 1989), it would suffice just to summarize the main findings. These are 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 h 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 (negligible) amount of NDMA. Although traces of *N*-nitrosopyrrolidine and *N*-nitrosodiethylamine had been detected in beer in rare instances (Havery *et al.*, 1981; Kawabata *et al.*, 1980; Spiegelhalder *et al.*, 1979), such occurrences are very uncommon and, therefore, require no further mention or discussion.

Following these discoveries, maltsters in various countries started adopting indirect malt drying techniques, but some still continued using the direct drying method with the sulfur-burning cycle extended from 25 to 40−50 g of S/100 kg of malt. Canadian malt companies were among the first ones in the world to switch to indirect drying malts used for the production of beer and ale. By the end of 1981, all had completely switched to indirect heating. As a result, NDMA levels in most Canadian beers declined to ≤0.1 ppb by 1982−1983 (Canadian Health Protection Branch, unpublished data). This ensured us that as far as domestic beer was concerned the problem of NDMA contamination had been resolved, and no further monitoring of domestic beer seemed necessary. But this was not true for all imported beers and ales. Hence it was felt that there was a need to continuously monitor imported beers until the NDMA levels in these products became comparable to those in the domestic beers. In this report, we wish to present some recent data on the NDMA levels in beers imported to Canada and to discuss trends in these levels during the past 15 years. For comparison, some

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Table 1. Trends in the Levels of NDMA in Canadian Beers

no. of samples analyzed and their sources	period analyzed	NDMA levels (ppb)	
		mean[a]	range
13 (all from the province of Ontario)[b]	1978	1.4	0.6–4.9
55 (national survey)[b]	1980	0.73	0.36–1.52
37 (all from the province of Ontario and Quebec)	Feb.–June 1982	0.1	N[c]–0.6
79 (national survey)	1982–1983	0.098	N–0.5
46 (not specified)[d]	1988–1989	0.095	N–0.59

[a] Zero was used for <0.1 ppb. [b] Reproduced from Sen *et al.* (1982). [c] N = undetectable (<0.1 ppb). [d] Data taken from Scanlan *et al.* (1990); although not mentioned, the samples were obtained from across the country (private communication).

of the earlier but unpublished data on Canadian beers are also included in this report.

MATERIALS AND METHODS

Beer Samples. The majority of the samples were procured from different provinces by Health Protection Branch Inspectors and shipped to either of the two (Ottawa or Longueuil) laboratories for analysis. In addition, some of the beers were purchased from local retail outlets in the Ottawa–Hull area. All samples at the Ottawa laboratory were stored at 4 °C, whereas most beers at the Longueuil laboratory were stored at room temperature except for those close to the expiration date. These were stored at 4 °C. All samples were analyzed within 1 month of procurement.

Sampling. In the two large surveys of the domestic Canadian beer and ales, most of the popular brands made by the three or four major producers were included for analysis. Smaller numbers of other beers and ales were also included that were either consumed less frequently or consumed only in certain regions of the country. Also, all types of beers, namely, lager, ale, and light and dark beers, were selected for the survey. Similarly, as many varieties as possible of imported beers were included in the various surveys although the majority of them were of European origin, for these beers are more frequently consumed by average Canadians than those from other countries, *e.g.*, the developing countries. If an initial survey indicated a problem (higher than average levels) with a certain brand of beer or with beers, in general, from a specific country, the follow up surveys were concentrated on those beers until their NDMA contents declined to acceptable levels. A detailed breakdown of the imported beers analyzed in the two most recent surveys (1992 and 1994) is presented under Results and Discussion.

Determination of NDMA. The beer samples were analyzed either by a distillation method (Sen *et al.*, 1982) or by a Celite column extraction method (Hotchkiss *et al.*, 1981; Cutaia *et al.*, 1982). Both are official AOAC International methods and have been shown to be highly accurate and reliable in two separate collaborative studies. The minimum detection limit of both methods is about 0.1 ppb.

RESULTS AND DISCUSSION

The results of the various surveys on the determination of NDMA levels in both domestic and imported beers along with their sources are presented in Tables 1 and 2, respectively. For comparison purposes and to demonstrate trends, some of the earlier data obtained prior to 1982 and those reported by Scanlan *et al.* (1990) for the Canadian beers have also been summarized in these tables. As can be seen from these data (Table 1), NDMA levels in the domestic Canadian beers had stabilized at around 0.1 ppb as early as February 1982. This decline seemed to have taken place in two stages—the first one to an average level of 0.73 ppb in 1980 and the second to an average level of 0.1 ppb in February–June, 1982. The highest level of NDMA detected in each survey also decreased in a similar manner. The first decline could be attributed to the introduction in March 1979 of a modified direct malt-drying technique by the three major Canadian malting companies in which the sulfur-burning cycle was extended to 40–50 g of S/100 kg of malt during the first 8–10 h of drying (Sen *et al.*, 1982). The second or the final decline occurred when all the maltsters in Canada switched to indirect drying by the end of 1981. It should be of interest that the levels of NDMA detected in Canadian beers by Scanlan *et al.* (1990) are very similar to those observed in the 1982–1983 Health Protection Branch survey suggesting that no further decline in NDMA levels has taken place over these years. Since no other major changes have been introduced in the Canadian malt-drying techniques after 1981, it is highly likely that NDMA levels in current Canadian beers are about the same as detected in the 1982–1983 survey.

Table 2. Trends in the Levels of NDMA in Beers Imported into Canada

no. of samples analyzed and their sources	period analyzed	NDMA levels (ppb)	
		mean[a]	range
9[b,c]	1978	1.65	N[d]–4.3
13[b,c]	1980	1.6	0.2–5.9
28[b,c]	1981	0.51	N–2.7
9[b,c]	Feb. 1982	0.31	N–0.5
51[e]	1982–1983	0.26	N–0.7
11[f]	1988	0.28	N–0.5
106[g]	1991–1992	0.71	N–9.1
36[g]	Oct.–Dec. 1994	0.15	N–3.2

[a] Zero was used for <0.1 ppb. [b] For the details of sources, see Sen *et al.* 1982. [c] Data reproduced from Sen *et al.* (1982). [d] N = undetectable (<0.1 ppb). [e] 10 from United States; 8 from Germany; 6 each from England and Holland; 3 each from Denmark, France, and Japan; 2 each from Austria, China, and Switzerland; and 1 each from Czechoslovakia, Philippines, Australia, South Africa, Scotland, and New Zealand. [f] 4 from England; 3 from Germany; and 1 each from Belgium, Holland, France, and Czechoslovakia. [g] Please see Table 3 for details.

The situation, however, was not as clear-cut with the imported beers (Table 2). Although the average NDMA levels in such products had also been declining gradually, such declines appeared to be more gradual, and there was a sudden increase noted in the 1991–1992 survey. This happened because some Mexican and Belgian beers, which were not included in the earlier surveys, contained high levels (up to 9.1 ppb) of NDMA. Since Canada imports greater than 110 brands of beers from many countries, it was not possible to include all of them in each survey. Instead, the imported beers which are consumed more frequently by average Canadian were analyzed first, and the less popular brands were introduced gradually in the subsequent surveys. A detailed breakdown of the imported beers analyzed in the two most recent surveys and the respective results are presented in Table 3. To our knowledge this appears to be the most comprehensive survey of beers from different countries reported in the literature regarding NDMA contamination.

The follow up survey (Tables 2 and 3) carried out during October–December 1994 indicated a marked improvement of the situation, especially for the Mexican (n = 8) and Belgian (n = 4) beers which were of the same brands as analyzed in the 1991–1992 survey. Analysis of a total of 36 imported beers gave an average NDMA level of 0.15 ppb (range, <0.1–3.2 ppb)—a value that is close to those detected in Canadian beers in the last three surveys (Table 1). Although it is realized that

Table 3. Details of Results of the Imported Beers Analyzed during 1991−1994

	NDMA levels (ppb) detected					
	1991−1992			1994 (Oct.−Dec.)		
country of origin	*n*	mean[a]	range	*n*	mean[a]	range
Austria	2	0.41	0.34−0.48			
Australia	5	0.27	0.13−0.52			
Belgium	13	1.02	N[b]−2.1	4	0.07	N−0.15
Brazil	1	0.21				
China	2	0.27	0.1−0.45	1	N	
Czechoslovakia	1	0.25				
Denmark	1	0.1		2	0.08	N−0.16
England	12	0.5	0.3−0.69	1	N	
France	4	0.64	0.32−1.29	2	N	
Germany	16	0.5	0.21−0.82	2	0.05	N−0.11
Holland	4	0.26	0.19−0.34	2	0.24	0.18−0.31
Ireland	3	0.05	N−0.15	1	N	
Israel	1	0.32				
Italy	2	1.05	0.35−1.75	1	N	
Jamaica	3	0.43	0.41−0.45	1	N	
Japan	4	0.33	0.27−0.35	1	N	
Kenya	1	N		1	N	
Mexico[c]	17	2.1	N−9.1	8	N	
Norway	1	0.48				
New Zealand	2	N		1	N	
Peru	1	0.18				
Philippines	2	0.19	0.15−0.23			
Poland				2	0.45	N−0.9
Portugal	1	0.31		1	N	
Russia	1	0.26				
Scotland	2	0.22	N−0.45			
Trinidad	1	N				
Thailand	1	0.3		1	N	
United States	1	0.7		4	0.86	N−3.2
Yugoslavia (former)	1	N				

[a] Zero was used for <0.1 ppb. [b] N = undetectable (<0.1 ppb). [c] NDMA in one of these beers containing 5.7 ppb NDMA was confirmed by GC−high-resolution mass spectrometry.

the number of samples analyzed in this followup survey is relatively small, the results are highly encouraging. It would be advisable to analyze additional samples to ensure that the decline observed in NDMA levels in these beers is real and not apparent.

Furthermore, there might be other imported beers in the Canadian market that have not been thoroughly investigated for NDMA contamination. For example, in a recent survey of 120 Indian beers, Prasad and Krishnaswamy (1994) detected an average of 3.2 ppb NDMA (range, <0.5−24.7 ppb). Similar high levels of NDMA might be present in beers from other developing countries. Since not much is known about the current malt-drying techniques in various countries, continuous monitoring and control of NDMA levels in imported beers becomes even more necessary. As far as the majority of the imported beers are concerned, the latest results are highly promising. Assuming an average level of 0.1 ppb NDMA in both domestic and imported beers and an average consumption level of 350 mL/person/day, the average daily intake of NDMA through beer by an average Canadian at the moment is approximately 0.035 μg/person/day. This is about one-fifteenth of that found in 1978−1980 (Sen *et al.*, 1980) and is comparable to the corresponding U.S. (0.026 μg) and German (0.028−0.093 μg) figures reported recently by Scanlan *et al.* (1990) and Tricker *et al.* (1991), respectively.

As mentioned earlier, NDMA is the only volatile nitrosamine normally detected in beer. Of the nonvolatile *N*-nitroso compounds, *N*-nitrosoproline (NPRO) is the major one detected thus far (Hotchkiss, 1989; Sen *et al.*, 1983; Tricker and Kubacki, 1992). Since NPRO is noncarcinogenic to laboratory animals, its presence in beer should not be of much concern. However, there might be other nonvolatile *N*-nitroso compounds in beer that deserve further studies. According to Massey *et al.* (1990), certain beers may contain unknown *N*-nitroso compounds in concentrations of 50−1480 ppb (values expressed in terms of NDMA), but nothing is known as to their identity. Additional research is urgently needed on the chemical characterization of these compounds. Without this information, it will be difficult to carry out a meaningful assessment of the health hazard that may arise from consumption of beer with regard to the presence of *N*-nitroso compounds.

SAFETY PRECAUTION

Since NDMA and most *N*-nitroso compounds are potent carcinogens, proper precaution should be taken while handling or working with these compounds.

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