FOOD ADDITIVES AND CONTAMINANTS, 1988, VOL. 5, NO. 4, 587–595

Volatile nitrosamines in foods on the Swedish market and estimation of their daily intake

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(Received 14 October 1987, revised 23 February 1988, accepted 19 March 1988)

Foods on the Swedish market in 1980–1986 were analysed for volatile *N*-nitrosamines using gas chromatography-thermal energy analysis. Detectable levels were found in 474 of the 764 samples analysed. The average daily intake of volatile *N*-nitrosamines was estimated to be 0·29 μg per person. Over 93% of the intake comes from meat and malt products.

Keywords: *N*-nitrosamines, foods, dietary intake, Sweden

Introduction

The presence of volatile *N*-nitrosamines in foods has given rise to considerable research since Ender and his colleagues (1964) reported the isolation and identification of *N*-nitrosodimethylamine (NDMA) in nitrite-treated fish meal. It is now well established that a wide variety of foods, particularly cured meat products and products dried using direct methods, contain trace amounts of volatile *N*-nitrosamines (Spiegelhalder *et al.* 1980, Maki *et al.* 1980, Scanlan 1983, Havery and Fazio 1985).

Josefsson and Nygren have previously reported on the levels of volatile *N*-nitrosamines in foods in Sweden (1981). They concentrated their study on samples of bacon, salt pork and sausages.

The purpose of the present study was to follow up the previous work on the occurrence of volatile *N*-nitrosamines in foods on the Swedish market and estimate the average daily intake of volatile *N*-nitrosamines.

Experimental

Sampling

Most of the samples of food were purchased from shops in Sweden in 1980–1986. All malt samples were obtained from breweries, and some samples of bacon were obtained from meat curing factories. All samples were normally analysed within 3 weeks after appropriate storage.

Materials

Dichloromethane and 2,2,4-trimethylpentane (analytical grade) were obtained from E. Merck AG (Darmstadt, FRG) and were used without further purification. The water used was deionized. Extrelut (E. Merck AG) was dried overnight at about 200°C prior to use and stored at the same temperature. All other chemicals were reagent grade or better. The organic solvents and deionized water were checked to ensure the absence of substances that could interfere with the analysis for

N-nitrosamines. Standard *N*-nitrosamine solutions (100 μg/ml) were obtained from the Thermo Electron Corp. (Waltham, MA, USA).

Methods

Earlier published methods were applied for the analyses. The possibility of formation of volatile *N*-nitrosamines during the vacuum distillation was minimized by addition of sodium hydroxide or ascorbic acid. Samples of meat, fish, cheese, canned baby food, and other undried products were analysed for volatile nitrosamines by a vacuum distillation method previously described by Josefsson and Nygren (1981). Briefly, the sample (20 g) was vacuum distilled with paraffin oil or glycerol. The aqueous distillate was extracted on an Extrelut column with dichloromethane and the extract was concentrated to about 0·5 ml.

For dried samples, e.g. dried milk, egg powder, cocoa, coffee, cereals and malt, the following method was used. A 10 g sample was mixed with 25 ml water and, after 10–15 minutes, 2 ml 6 M sodium hydroxide, 20 ml glycerol, and 250 μl of a solution of *N*-nitrosodipropylamine or *N*-nitrosodiisopropylamine (NDPA or NDiPA; 400 ng/ml), as an internal standard, were added. The sample was then vacuum distilled and worked up as described by Josefsson and Nygren (1981).

Beer and other liquids were analysed for volatile nitrosamines by a column elution method (Österdahl 1983). Samples of whisky and other spirits (5·0 ml) were diluted with 15 ml water before analysis. To 20·0 ml of sample was added 1 ml 2·5 M sulphuric acid and 250 μl of a solution of NDPA (400 ng/ml) as an internal standard. The mixture was poured onto an Extrelut column (25 cm × 20 mm ID) and after 10 to 15 min the nitrosamines were eluted with 2 × 25 ml dichloromethane. The combined dichloromethane eluates were concentrated to about 0·5 ml in a water bath at 55°C. Towards the end of the concentration, 200 μl 2,2,4-trimethylpentane was added as a 'keeper'. The final volume was measured with a 1000 μl Hamilton syringe.

Analyses were carried out using an isothermal gas-liquid chromatograph (GLC; Varian 2700, Palo Alto, CA, USA) interfaced with a Thermal Energy Analyzer (TEA; Model 502, Thermo Electron Corp.). For detection and quantification, 5 μl portions were analysed against external standards by injection into a 1·8 m × 1·9 mm (ID) glass column containing 20% Carbowax 20 M and 2% KOH on Chromosorb W, AW-DMCS, 80/100 mesh. The normal GLC-TEA conditions were; column temperature 140°C, injector temperature 200°C, helium carrier-gas flow about 27 ml/min, furnace temperature 475°C, oxygen flow 5 ml/min, vacuum pressure about 1 mm Hg and cold-trap temperature −160 to −150°C. In some analyses the cold-trap was replaced by a CTR Gas Stream Filter (Thermo Electron Corp.).

The detection limits of the method were 0·1–0·3 μg nitrosamine/kg.

Results and discussion

The analytical results are shown in Tables 1–4. All values are corrected for recovery of NDPA or NDiPA used as an internal standard. The recovery was normally above 80%: if recovery was below 70%, the sample was reanalysed. Nearly all values in the tables are from single determinations. Our within-laboratory coefficient of variation for determinations of volatile *N*-nitrosamines in foods is between 5 and 15%.

Table 1 summarizes the results from the analysis of all 764 samples of food.

Table 1. Volatile N-nitrosamines in foods on the Swedish market, 1980–1986.

Food	No. of samples	No. of positives[1]	Mean level of nitrosamines (μg/kg)				
			NDMA	NDBA	NPIP	NPYR	TOTAL
Bacon, fried	68	68	1·7	ND[2]	Tr[3]	7·6	9·3
Smoked pork, fried	21	20	0·9	ND	0·1	4·0	5·0
Salt pork, fried	18	17	0·8	ND	ND	2·6	3·4
Smoked meat products	23	16	0·8	0·3	0·1	0·1	1·3
Other meat products	14	6	0·1	ND	0·7	ND	0·8
Smoked fish	61	55	1·3	ND	ND	ND	1·3
Fried Baltic herring	5	5	2·3	ND	ND	ND	2·3
Raw-pickled salmon	8	2	0·6	ND	ND	ND	0·6
Fermented Baltic herring	1	0	ND	ND	ND	ND	ND
Caviar and roe	5	5	0·2	ND	ND	ND	0·2
Smoked clams	1	1	1·6	ND	ND	0·4	2·0
Beer	258	153	0·3	ND	Tr	ND	0·3
Other malt beverages	13	6	0·2	ND	ND	ND	0·2
Whisky	15	11	1·2	ND	ND	ND	1·2
Other spirits	13	2	0·1	ND	ND	ND	0·1
Wine	60	0	ND	ND	ND	ND	ND
Malt, domestic	16	16	0·6	ND	ND	Tr	0·6
imported	10	10	3·3	ND	ND	0·2	3·5
Dried milk	27	3	Tr	ND	ND	ND	Tr
Sauce mixes	9	5	0·2	ND	ND	0·3	0·5
Soup powders	11	8	1·9	ND	ND	ND	1·9
Egg powder	3	2	0·7	ND	ND	ND	0·7
Spice mixture	4	4	1·5	ND	1·3	0·7	3·5
Cocoa	12	11	0·5	ND	ND	1·0	1·5
Chocolate bar	15	11	0·1	ND	ND	ND	0·1
Chocolate beverage powders	2	1	0·1	ND	ND	ND	0·1
Tea	6	6	0·6	ND	ND	ND	0·6
Coffee	16	12	0·1	ND	ND	0·2	0·3
Cereal products	11	8	0·3	ND	ND	ND	0·3
Cheese	12	4	ND	ND	0·1	ND	0·1
Soya sauce	4	0	ND	ND	ND	ND	ND
Canned baby food	16	6	Tr	ND	ND	ND	Tr
Miscellaneous products	6	0	ND	ND	ND	ND	ND

[1] > 0·1–0·3 μg/kg. [2] ND = Not detected. [3] Tr = Trace.

Table 2. *N*-Nitrosopyrrolidine (NPYR) levels in fried samples of domestic and imported bacon.

Source of bacon	No. of samples	No. of samples with NPYR levels (μg/kg) of					Mean level of NPYR (μg/kg)
		< 0·2	0·2–4·9	5·0–9·9	10·0–14·9	> 15·0	
Domestic							
from factories	21	6	15	0	0	0	0·6
from retail shops	32	1	18	7	5	1	5·6
Imported							
from retail shops	15	0	1	2	3	9	21·7

Table 3. *N*-Nitrosodimethylamine (NDMA) levels in smoked fish.

Type of fish	No. of samples	No.of samples with NDMA levels (μg/kg) of				Mean level of NDMA (μg/kg)
		< 0·1	0·1–0·9	1·0–4·9	> 5·0	
Baltic herring	16	0	4	9	3	3·0
Char	4	0	2	1	1	2·0
Mackerel	10	1	7	2	0	1·0
Salmon	7	2	4	1	0	0·7
Whitefish	10	0	8	2	0	0·5
Rainbow trout	4	0	4	0	0	0·4
Plaice	2	0	2	0	0	0·3
Eel	8	3	5	0	0	0·1

Table 4. *N*-nitrosodimethylamine (NDMA) levels in domestic and imported beers.

Source and type of beer (alcohol %)	No. of samples	No. of samples with NDMA levels (μg/l) of				Mean level of NDMA (μg/l)
		< 0·1	0·1–0·9	1·0–4·9	> 5·0	
Domestic						
Beer ⩽ 4·5%	100	35	58	6	1	0·40
Beer ⩽ 2·8%	70	40	28	2	0	0·25
Beer ⩽ 1·8%	25	18	7	0	0	0·06
Imported						
Beer ⩽ 4·5%	51	8	38	4	1	0·67
Beer ⩽ 2·8%	12	5	7	0	0	0·15
Nonalcoholic beer	4	0	4	0	0	0·42

NDMA was the most frequently occurring volatile *N*-nitrosamine. *N*-Nitrosopyrrolidine (NPYR) was found almost exclusively in fried bacon, pork, cocoa, and coffee. *N*-Nitrosodibutylamine (NDBA) and *N*-nitrosopiperidine (NPIP) were found in a few samples. The highest levels of volatile *N*-nitrosamines were found in fried bacon and pork. Besides those, only occasional samples contained volatile *N*-nitrosamines above the 5 μg/kg level.

Most of the results on beer, bacon and other meat products have been published earlier in Swedish (Österdahl 1983, 1985, Österdahl and Olsson 1983) and are summarized here.

Trace levels of NDMA, NPIP and NPYR were found in raw samples of bacon and pork. After frying at 175°C for 3 min per side, NPYR and NDMA were found in all bacon samples, and in all but one sample of smoked and salt pork. NPIP was present at low levels in a few samples. The NPYR content of fried bacon is shown in Table 2. After frying, bacon obtained directly from factories contained lower levels of nitrosamines than bacon purchased in shops. Imported bacon samples contained significantly higher levels of nitrosamines than domestic bacon samples. The highest level of NPYR detected (56 μg/kg) was in an imported bacon sample (Osterdahl and Olsson, 1983). It is hard to explain these differences but they may be due to differences in manufacturing methods. In Sweden, all bacon is produced using smoke flavours. Recently, Ikins *et al.* (1986) found lower concentrations of NDMA, NPYR and *N*-nitrosothiazolidine in fried bacon produced with smoke flavours than

in bacon produced by the traditional wood smoke process. The low levels in bacon samples from factories compared to those purchased in shops could be due to the effect of storage.

Fifteen samples of cooked-out fat contained the same level of volatile *N*-nitrosamines as the corresponding fried bacon—mean levels 8·2 and 11·8 μg/kg, respectively (Österdahl and Olsson 1983).

Two samples of smoked chicken contained NDBA (0·9 and 5·3 μg/kg, respectively), which is a very uncommon nitrosamine in food. Trace levels of NDBA have earlier been reported in a few samples of chicken frankfurters (Gray *et al.* 1981), and in two samples of fish (Yamamoto *et al.* 1984).

NPIP was detected in most samples of pepper sausage and pepper steak, but was rarely found in any other meat product, except a few samples of bacon and pork. NPIP has earlier been reported in cured meat products (Sen *et al.* 1979).

The levels of volatile *N*-nitrosamines in fish are shown in Tables 1 and 3. NDMA was the only volatile *N*-nitrosamine detected, and was present in most of the fish samples. The highest levels of NDMA were present in smoked or fried fish. All 16 samples of smoked Baltic herring, the most popular smoked fish in Sweden, contained NDMA at levels between 0·3 and 12·0 μg/kg, and all 5 samples of fried Baltic herring contained between 0·9 and 4·4 μg/kg. NDMA was also present at detectable levels (up to 5·4 μg/kg) in all 4 samples of smoked char. In 9 of 10 samples of smoked mackerel NDMA was found at concentrations up to 4·1 μg/kg. Five of 7 samples of smoked salmon, and 2 of 8 samples of raw-pickled salmon contained NDMA at levels between 0·2 and 3·6 μg/kg.

All samples of whitefish, rainbow trout and plaice contained NDMA in the range 0·1 to 1·1 μg/kg, but only trace levels of NDMA ($< 0{\cdot}2$ μg/kg) could be detected in smoked eel. The reason for the low levels in eel is probably that the skin was removed before analysis. No significant differences in content of NDMA could be observed in cold-smoked and hot-smoked fish. Traces (0·1 μg/kg) of NDMA were found in all samples of caviar and roe.

About 290 samples of beer, whisky and other beverages based on malt were analysed for volatile *N*-nitrosamines (Table 1). NDMA was detected in 59% of the samples examined. NDMA levels in domestic and imported beer are shown in Table 4. Only two of 258 samples of beer had NDMA levels over 5·0 μg/l, the highest value obtained being 6·5 μg/l. Strong beer contained higher levels of NDMA than light beers. No significant differences in the NDMA content could be observed between domestic and imported beer purchased on the Swedish market. On the other hand, the NDMA content varied in beer from different breweries, depending on the kind of malt they use. Beer from domestic breweries that used largely imported malt, particularly from the German Democratic Republic, had a higher content of NDMA than beer from other domestic breweries (Österdahl 1983).

The levels of NDMA in imported malt were significantly higher than those in domestic malt (Table 1). The two Swedish malt manufacturers use indirect drying. In only one of 34 samples of beer brewed using indirect dried malt could detectable levels of NDMA ($> 0{\cdot}1$ μg/l) be found.

The mean level of NDMA in beer on the Swedish market has decreased by over 80% during the period 1980 to 1985 to about 0·2 μg/l in both domestic and imported beer (Österdahl 1985). It is evident that changes in the malt drying process are the reason for this decrease in NDMA level in beer. Trace amounts of NPIP were found in a few samples of beer.

In 11 of 15 samples of whisky NDMA was present at concentrations up to 1·2 μg/l. Two of 13 samples of other spirits contained NDMA above the detection level. All 60 samples of wine were negative.

Low levels of volatile *N*-nitrosamines were found in a wide range of dried food samples, despite the fact that direct drying is unusual in Sweden. All dried milk in Sweden is dried by indirect methods, and NDMA could only be detected in 3 of 27 samples at concentrations of about 0·2 μg/kg. Trace levels of NDMA could also be observed in 13 of 20 samples of sauce mixes and soup powders. The highest levels were found in fish and shrimp soup powders, 7·2 and 5·0 μg/kg, respectively. Traces of NDMA have earlier been found in dried milk and a few samples of soup powders (Sen and Seaman 1981, Havery *et al.* 1982). Two of 3 samples of indirect dried egg powder contained low levels of NDMA. In all 4 samples of spice mixtures NDMA and NPYR were detected at levels between 0·4 and 3·8 μg/kg, and NPIP was present in 3 samples at levels from 0·6 to 3·5 μg/kg.

Nearly all samples of cocoa and chocolate products contained NDMA, at levels up to 1·2 μg/kg. NPYR was detected only in samples of cocoa; in 11 of 12 samples the NPYR concentration ranged from 0·4 to 2·3 μg/kg. All cocoa in Sweden is imported dried, and no information is available concerning the drying method used. As expected, the NDMA levels in samples of chocolate bars and beverage powders examined were lower than that in the pure dried cocoa. Trace levels, up to 0·3 μg/kg, were detected in 12 of 17 samples.

All 6 samples of tea contained NDMA at levels up to 1·2 μg/kg, but NDMA could not be detected in the brewed tea.

NDMA was found in 8 of 13 samples of fine-ground coffee, and in all 3 samples of instant coffee, at levels between 0·1 and 0·8 μg/kg. Six of 13 samples of fine-ground coffee and all 3 samples of instant coffee contained NPYR at levels between 0·1 and 0·5 μg/kg. Low levels of NPYR have earlier been reported in instant coffee and roasted ground coffee (Sen and Seaman 1981, Sen *et al.* 1982). However, no volatile *N*-nitrosamines could be detected in brewed coffee.

In 8 of 11 samples of cereal products NDMA was present at concentrations between 0·2 and 0·9 μg/kg. Recently, NDMA was detected in wheaten cornflour and maize meal (Weston 1984). No NDMA, but low levels of NPIP, was detected in 4 of 12 samples of cheese. None of the soya sauce samples contained detectable amounts of volatile *N*-nitrosamines. In 6 of 16 samples of canned baby food traces of NDMA (0·1 μg/kg) were found. No volatile *N*-nitrosamines could be detected in 6 samples of miscellaneous products—gruel, frying fat and stuffed cabbage roll.

The intake of volatile *N*-nitrosamines can be calculated from the analytical results obtained and the average intake of the foods concerned, see Table 5. Foods which are consumed in extremely small amounts have been omitted from the calculation, even though detectable amounts of volatile *N*-nitrosamines have been found in some of them. The average intakes of NDMA and of all volatile *N*-nitrosamines were calculated to be 44·7 and 104·5 μg/person/year, respectively. This corresponds to an average daily intake for NDMA of 0·12 μg, and for all volatile *N*-nitrosamines of 0·29 μg.

Table 6 shows the contribution of different foods to the average intake of volatile *N*-nitrosamines. Over 93% of the intake comes from meat and malt products. Meat and meat products contribute 61%, and beer and other malt products 32% of the dietary NDMA intake. With regard to all volatile *N*-nitrosamines, the relative contributions are 80% for meat and meat products and

Table 5. Estimated average intake of NDMA and total volatile *N*-nitrosamines from Swedish food.

Food	Consumption 1984[1] (kg/person/year)	Mean nitrosamine levels (μg/kg)		Estimated intake (μg/person/year)	
		NDMA	TOTAL	NDMA	TOTAL
Bacon	0·8	1·7	9·3	1·4	7·4
Salt or smoked pork	8·2	0·9	4·3	7·4	35·3
Other meat products	36·8	0·5	1·1	18·4	40·5
Smoked fish	0·2	1·3	1·3	0·3	0·3
Caviar and roe	0·7	0·2	0·2	0·1	0·1
Beer	45·2	0·3	0·3	13·6	13·6
Other malt beverages	0·6	0·2	0·2	0·1	0·1
Whisky	0·5	1·2	1·2	0·6	0·6
Soup powder	0·1	1·9	1·9	0·2	0·2
Spice mixture	0·1	1·5	3·5	0·1	0·3
Cocoa	0·2	0·5	1·5	0·1	0·3
Chocolate bar	5·6	0·1	0·1	0·6	0·6
Chocolate beverages powders	0·9	0·1	0·1	0·1	0·1
Tea	0·3	0·6	0·6	0·2	0·2
Coffee	9·2	0·1	0·3	0·9	2·8
Cereal products	2·1	0·3	0·3	0·6	0·6
Cheese	14·8	ND	0·1	0	1·5
Total				44·7	104·5

[1] National Agricultural Market Board (1985)

Table 6. Contribution of different products to the average intake of NDMA and total volatile *N*-nitrosamines from Swedish food.

Food	Percentage of total NDMA intake	Percentage of total volatile *N*-nitrosamine intake
Meat and meat products	61	80
Beer and other malt beverages	32	14
Smoked fish and caviar	1	0·5
Dried products	6	5
Cheese	—	1·5

14% for beer. Dried foods contribute about 5% of both NDMA and volatile *N*-nitrosamine intake.

Spiegelhalder *et al.* (1980) demonstrated that the total daily intakes of NDMA and NPYR by males in West Germany were 1·1 μg and 0·15 μg, respectively. About 64% of the NDMA intake was derived from the consumption of beer. The intake was lower for women. Gough *et al.* (1978) calculated the intake of volatile *N*-nitrosamines via the UK diet to be 0·53 μg/day. However, this study did not include data for beer. Using a duplicate portion sampling technique, Stephany and Schuller (1980) estimated a mean NDMA intake of 0·38 μg/day in The Netherlands. They calculated that beer contributes 71% of the intake. Maki *et al.* (1980)

estimated the daily intake of volatile *N*-nitrosamines from Japanese foods to be 1·8 μg. Later, Yamamoto *et al.* (1984) calculated the intake from Japanese food to be 0·5 μg/day. Fish products contribute 88% of that intake. In the latter study lower levels of *N*-nitrosamines were found in dried fish, which explains the difference in the estimates.

The calculated daily intake of volatile *N*-nitrosamines from Swedish food, 0·29 μg/person, is in good agreement with the data above. The slightly lower figure can be explained by the low levels of NDMA found in beer, and the relatively low beer consumption in Sweden.

Acknowledgements

The author is very grateful to Ing-Marie Olsson, Kristina Gustafson, Annétte Åberg-Vikholm, Virve Nylund, Arne Nyman and Brita Edward for skilful technical assistance.

References

ENDER, F., HAVRE, G., HELGEBOSTAD, A., KOPPANG, N., MADSEN, R., and CEH, L., 1964. Isolation and identification of a hepatotoxic factor in herring meal produced from sodium nitrite preserved herring. *Naturwissenschaften*, **51**, 637–638.

GOUGH, T. A., WEBB, K. S., and COLEMAN, R. F., 1978. Estimate of the volatile nitrosamine content of UK food. *Nature*, **272**, 161–163.

GRAY, J. I., BUSSEY, D. M., DAWSON, L. E., PRICE, J. F., STEVENSON, K. E., OWENS, J. L., and ROBACH, M. C., 1981. Investigation into the formation of *N*-nitrosamines in heated chicken frankfurters. *Journal of Food Science*, **46**, 1817–1819.

HAVERY, D. C., HOTCHKISS, J. H., and FAZIO, T., 1982. Rapid determination of volatile *N*-nitrosamines in nonfat dry milk. *Journal of Dairy Science*, **65**, 182–185.

HAVERY, D. C., and FAZIO, T., 1985. Human exposure to nitrosamines from foods. *Food Technology*, **39** (1), 80–83.

IKINS, W. G., GRAY, J. I., MANDAGERE, A. K., BOOREN, A. M., PEARSON, A. M., and STACHIW, M. A., 1986. *N*-Nitrosamine formation in fried bacon processed with liquid smoke preparations. *Journal of Agricultural and Food Chemistry*, **34**, 980–985.

JOSEFSSON, E., and NYGREN, S., 1981. Volatile *N*-nitroso compounds in foods in Sweden. *Vår Föda* **33** (Suppl. 2), 147–165.

MAKI, T., TAMURA, Y., SHIMAMURA, Y., and NAOI, Y., 1980. Estimate of the volatile nitrosamine content of Japanese food. *Bulletin of Environmental Contamination and Toxicology*, **25**, 257–261.

NATIONAL AGRICULTURAL MARKET BOARD—Statens Jordbruksnämnd, 1985. *Konsumtion i Sverige av livsmedel mm 1982–1984*. Jönköping.

ÖSTERDAHL, B.-G., 1983. Volatile *N*-nitrosamines in beer and other alcoholic beverages. *Vår Föda*, **35**, 221–230 (in Swedish with English summary).

ÖSTERDAHL, B.-G., and OLSSON, I.-M., 1983. Volatile nitrosamines in bacon, pork and other meat products. *Vår Föda*, **35**, 440–450 (in Swedish with English summary).

ÖSTERDAHL, B.-G., 1985. *N*-Nitrosodimethylamine in beer. *Vår Föda*, **37**, 397–400 (in Swedish with English summary).

SCANLAN, R. A., 1983. Formation and occurrence of nitrosamines in food. *Cancer Research (Suppl. 5)*, **43**, 2435s–2440s.

SEN, N. P., SEAMAN, S., and MILES, W. F., 1979. Volatile nitrosamines in various cured meat products: Effect of cooking and recent trends. *Journal of Agricultural and Food Chemistry*, **27**, 1354–1357.

SEN, N. P., and SEAMAN, S., 1981. Volatile *N*-nitrosamines in dried foods. *Journal of the Association of Official Analytical Chemists*, **64**, (5), 1238–1242.

SEN, N. P., SEAMAN, S., and TESSIER, L., 1982. A rapid and sensitive method for the determination of non-volatile *N*-nitroso compounds in foods and human urine: Recent data concerning volatile *N*-nitrosamines in dried foods and malt-based beverages. N-*Nitroso Compounds: Occurrence and*

Biological Effects edited by H. Bartsch, M. Castegnaro, I. K. O'Neill, M. Okada, and W. Davis (Lyon: Int. Agency for Research on Cancer), IARC Sci. Publ. No. 41, pp 185–197.

SPIEGELHALDER, B., EISENBRAND, G., and PREUSSMANN, R., 1980. Occurrence of volatile nitrosamines in food: A survey of the West German market. N-*Nitroso Compounds: Analysis, Formation and Occurrence* edited by E. A. Walter, L. Gricicute, M. Castegnaro, and M. Borzonyi (Lyon: Int. Agency for Research on Cancer), IARC Sci. Publ. No. 19, pp 467–475.

STEPHANY, R. W., and SCHULLER, P. L., 1980. Daily dietary intakes of nitrate, nitrite and volatile *N*-nitrosamines in The Netherlands using the duplicate portion sampling technique. *Oncology*, **37**, 203–210.

WESTON, R. J., 1984. Analysis of cereals, malted foods and dried legumes for *N*-nitrosodimethylamine. *Journal of Science of Food and Agriculture*, **35**, 782–786.

YAMAMOTO, M., IWATA, R., ISHIWATA, H., YAMADA, T., and TANIMURA, A., 1984. Determination of volatile nitrosamine levels in foods and estimation of their daily intake in Japan. *Food and Chemical Toxicology*, **22** (1), 61–64.