Chemical Composition of Smokeless Tobacco Products[1]

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ABSTRACT To date, 28 carcinogens have been identified in smokeless tobacco. In addition to certain volatile aldehydes, traces of benzo[*a*]pyrene, certain lactones, urethan, hydrazine, metals, polonium-210, and uranium-235 and -238 can be found in ST. However, the major contributors to the carcinogenicity of chewing tobacco and of snuff are the *N*-nitrosamines, especially the tobacco-specific *N*-nitrosamines. The latter are formed from the *Nicotiana* alkaloids during tobacco processing. In the United States, daily exposure to carcinogenic nitrosamines for snuff users is at least 250 times higher than for those who do not use tobacco. Although there has been a decline in the concentrations of nitrosamines in U.S. and Swedish ST products during the past decade, this trend is not evident for all snuff brands. One new snuff brand contains extremely high concentrations of carcinogenic nitrosamines. This observation adds to the urgency of the recommendation of the World Health Organization to regulate harmful substances in chewing tobacco and snuff. Similarly, flavorants and additives to tobacco should be controlled.

INTRODUCTION In the United States, we differentiate between four primary types of smokeless tobacco: Three are chewing tobaccos, namely loose leaf (scrap leaf), plug, and twist or roll; the fourth is oral snuff. Loose leaf chewing tobacco accounted for 52.7 percent of the U.S. output of total ST products in 1988 (124.5 million lb) (USDA, 1990). Loose leaf chewing tobacco consists primarily of air-cured tobacco and, in most cases, is heavily treated with licorice and sugars. Plug tobacco (7.2 percent of 1988 ST production) is the oldest form of chewing tobacco. Plug tobacco is produced from the heavier grades of leaves harvested from the top of the plant, freed from stems, immersed in a mixture of licorice and sugar, pressed into a plug, covered by a wrapper leaf, and reshaped. Plug tobacco is kept between cheek and gum and is chewed in bites. Twist or roll tobacco is less important (1.1 percent of 1988 U.S. production). Twist tobacco is made from cured burley, and air- and fire-cured leaves, which are flavored and twisted to resemble a decorative rope or pigtail.

The only U.S. tobacco product with increasing consumption is oral snuff (39.0 percent of the U.S. smokeless tobacco production in 1988). Dry snuff is made primarily from Kentucky and Tennessee fire-cured tobaccos. The initial curing requires several weeks and goes through multiple phases. In contrast to most other tobacco products, snuff undergoes an additional fermentation process. Dry snuff is processed into a powdered substance that may contain flavor and aroma additives, including spices. U.S. dry snuff, which is taken orally, is similar to European nasal snuff.

Moist snuff consists primarily of air- and fire-cured tobaccos and contains tobacco stems as well as leaves that are powdered into fine particles (containing between 20 and 55 percent moisture). Many brands of moist

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snuff are flavored with wintergreen, but mint and raspberry also are popular. Since about 1975, the consumption of moist snuff has been steadily growing in all parts of the United States, except for a temporary decline immediately after the Surgeon General's report on smokeless tobacco in 1986 (US DHHS, 1986). During the past 3 yr, the manufacture of moist snuff has again steadily risen by more than 13 percent (Smyth, 1989; USDA, 1990). Oral use of snuff, also termed "snuff dipping," means placing a pinch of the tobacco between the cheek or lip and the gums or beneath the tongue.

CHEMICAL COMPOSITION

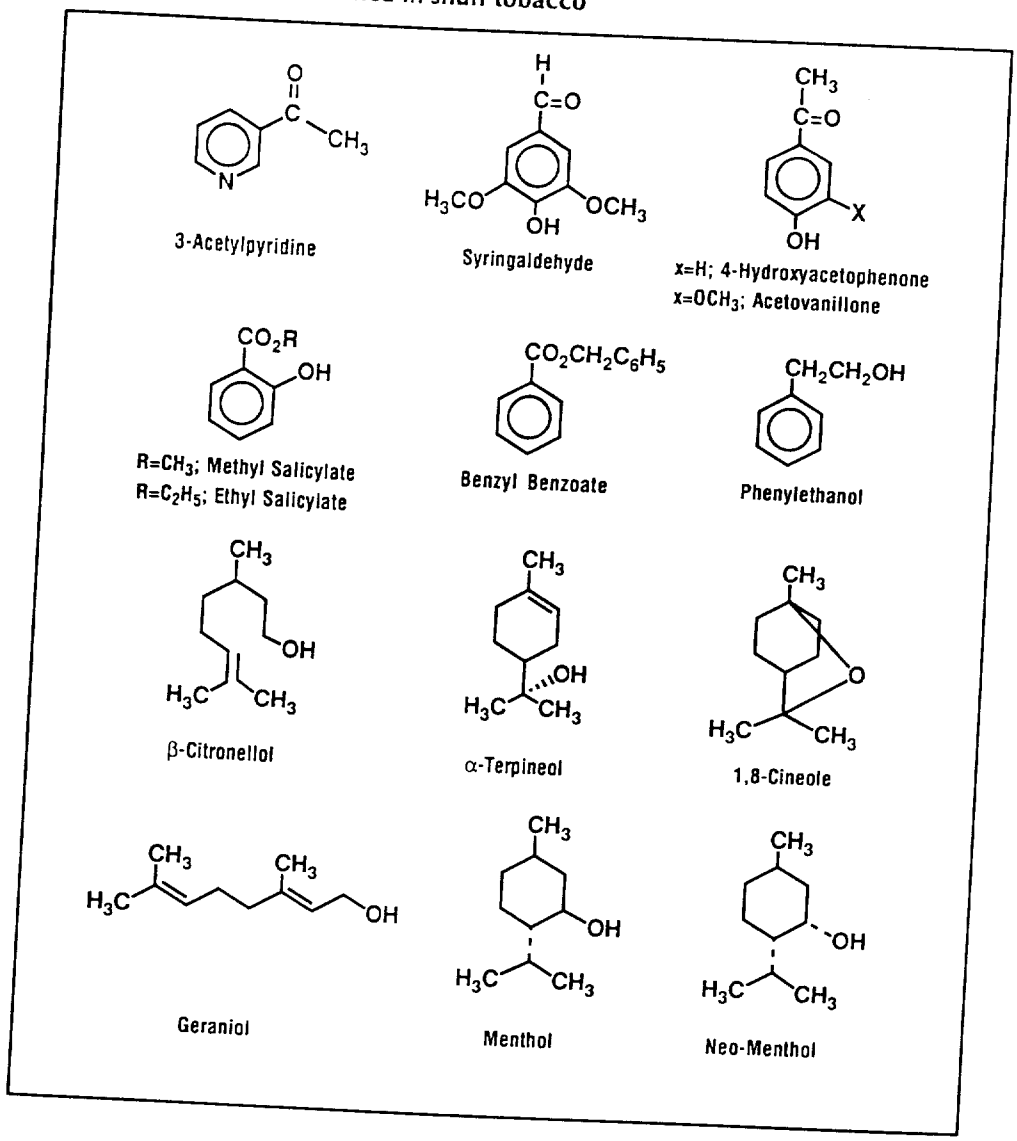
Extensive literature on the chemistry of tobacco, beginning with Brückner (1936), has led to our current knowledge that natural tobacco contains at least 3,050 different components (Robert, 1988). The quantitative composition of tobacco undergoes substantial changes during processing for smokeless tobaccos. In curing, the starch content of the leaves declines drastically, and the reducing sugars increase by 100 percent. Protein and nicotine decrease slightly. Fermentation of cured tobacco causes the contents of carbohydrates and polyphenols in the leaves to diminish. The bulk of the processed tobacco leaf before fermentation consists of carbohydrates (about 50 percent) and proteins. Other major components are alkaloids (0.5 to 5.0 percent) with nicotine as the predominant compound (85 to 95 percent of total alkaloids), terpenes (0.1 to 3.0 percent), polyphenols (0.5 to 4.5 percent), phytosterols (0.1 to 2.5 percent), carboxylic acids (0.1 to 0.7 percent), alkanes (0.1 to 0.4 percent), aromatic hydrocarbons, aldehydes, ketones, amines, nitriles, *N*- and *O*-heterocyclic hydrocarbons, pesticides, alkali nitrates (0.01 to 5.00 percent), and at least 30 metallic compounds (International Agency for Research on Cancer, 1985; Wynder and Hoffman, 1967). The given percentages apply to the *Nicotiana tabacum* species, which is grown in North America and throughout the world, but not to *N. rustica*, which is cultivated in parts of Eastern Europe and Asia Minor. The leaves of *N. rustica* may contain up to 12 percent nicotine (McMurtrey et al., 1942). Many ST formulations use plant extracts or chemicals as flavoring agents (LaVoie et al., 1989; Mookherjee, 1988; Robert, 1988; Sharma et al., 1991). Such additives may include methyl or ethyl salicylate, β-citronellol, 1,8-cineole, menthol, benzyl benzoate, and possibly coumarin (Figure 1) (LaVoie et al., 1989; Sharma et al., 1991). However, most of the flavor additives are present in only small amounts; their formulations remain trade secrets.

CARCINOGENIC AGENTS IN ST

Until now, 28 tumorigenic agents have been isolated and identified in smokeless tobacco products (Table 1). These include some carcinogenic polynuclear aromatic hydrocarbons (PAH), especially benzo[*a*]pyrene (B[*a*]P). PAH originate primarily from polluted air (Campbell and Lindsay, 1956 and 1957; Wynder and Hoffmann, 1967) and, in the case of plug tobacco and snuff, probably also from fire-curing. In fact, the highest reported values for B[*a*]P were found in snuff at levels of up to 90 ppb (Ough, 1976).

The α- and β-angelica lactones have been reported in natural tobacco (Robert, 1988). These tumorigenic agents may also be added to ST as part of the flavoring mixtures made from plant extracts. A minor group of polyphenols in tobacco are the coumarins, of which scopoletin is the major

Figure 1
Flavor compounds identified in snuff tobacco



representative (Figure 2) (Wynder and Hoffmann, 1967). Thus, it is not surprising that tobacco also contains the parent compound, coumarin (≤ 600 ppm). It is known that the fermentation of food and beverages leads to the formation of urethan (Ough, 1976). Therefore, it is not unexpected that burley tobacco, which is fermented, contains up to 400 ppm of urethan (Schmoltz et al., 1978).

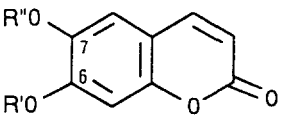
The most abundant carcinogens in smokeless tobacco are some volatile aldehydes (Table 1). Although formaldehyde, acetaldehyde, and crotonaldehyde are weakly carcinogenic, they contribute most likely to the carcinogenic potential of smokeless tobacco (Weybrew and Stephens, 1962). It is

Table 1
Carcinogenic agents in tobacco

	Type of Tobacco[a]	Concentration[b] (ng/g)
Benzo[a]pyrene	NT, S	> 0.1 - 90.0
α-Angelica Lactone	NT	present
β-Angelica Lactone	NT	present
Coumarin	NT	600
Ethylcarbamate	CT	310 - 375
Volatile Aldehydes		
Formaldehyde	NT, S	1,600 - 7,400
Acetaldehyde	NT, S	1,400 - 27,400
Crotonaldehyde	S	200 - 2,400
Nitrosamines		
Nitrosodimethylamine	CT, S	ND - 270
Nitrosopyrrolidine	CT, S	ND - 760
Nitrosopiperidine	CT, S	ND - 110
Nitrosomorpholine	CT, S	ND - 690
Nitrosodiethanolamine	CT, S	40 - 6,800
Nitrosamino Acids		
Nitrososarcosine	S	ND - 2,500
3-(methylnitrosamino)-propionic acid	CT, S	200 - 65,700
4-(methylnitrosamino)-butyric acid	CT, S	ND - 9,100
Nitrosoazetadine-2-carboxylic acid	CT	4 - 140
Tobacco-Specific Nitrosamines		
N'-nitrosonornicotine	CT, S	400 - 147,000
4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone	CT, S	ND - 18,000
4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol	S	present
N'-nitrosoanabasine	SM, S	present - 560
Inorganic Compounds		
Hydrazine	SM	14 - 51
Arsenic	NT	500 - 900
Nickel	SM, S	180 - 2,700
Cadmium	SM	700 - 790
		(pCi/g)
Polonium-210	NT, S	0.16 - 1.22
Uranium-235	S	2.4
Uranium-238	S	1.91

[a] *NT, natural tobacco; SM, smoking tobacco; S, snuff; CT, chewing tobacco.*
[b] *ND, not detected.*

Figure 2
Coumarins in tobacco



Scopoletin	R' = H	R" = CH_3
Scopolin	R' = *d*-Glucosyl	R" = CH_3
Fabiatin	R' = Primverosyl (xylosido-*d*-glucosyl)	R" = CH_3
Scopoletin-β-gentiobioside	R' = 6-Glucosido-*d*-glucosyl	R" = CH_3
Esculetin	R' = H	R" = H
Cichoriin	R' = *d*-Glucosyl	R" = H

known that tobacco contains a sizeable spectrum of alkyl aldehydes, which contribute to its scent. In commercial U.S. snuff brands, formaldehyde and acetaldehyde were each found up to 7,400 ppb, and crotonaldehyde up to 2,400 ppb (Sharma et al., 1991).

Both air- and fire-cured tobaccos contain hydrazine. In burley leaves treated with the sucker growth inhibitor maleic hydrazide, the hydrazine content was significantly higher (Liu et al., 1974). Like other plant products, tobacco contains trace amounts of nickel, cadmium, and arsenic. These animal carcinogens were found in concentrations up to 2,700 ppb. Uranium-235 and -238 were reported only in Indian snuff, each at about 2 pCi/g tobacco (Sharma et al., 1985). The radioactive polonium-210, which decays to yield the human carcinogen radon, originates in U.S. tobacco from soil that is fertilized with phosphates rich in radium-226 (Tso et al., 1986), or from airborne particles that were taken up by the glandular hair (trichomes) of the tobacco leaf (Martell, 1974). In U.S. commercial snuff, we found between 0.16 and 1.22 pCi/g of polonium-210 (Hoffmann et al., 1987).

CARCINOGENIC *N*-NITROSAMINES The most detailed studies on carcinogens in smokeless tobacco have been reported for *N*-nitrosamines. These agents are present in fresh green leaf in only minute amounts and are primarily formed during curing, fermentation, and aging from secondary or tertiary amines and nitrite or nitrogen oxides. Basically, in smokeless tobacco there are three types of nitroso compounds: volatile nitrosamines, nitrosamino acids, and tobacco-specific *N*-nitrosamines (TSNA). In addition, smokeless tobacco contains *N*-nitrosodiethanolamine (NDELA), which is formed from diethanolamine, a contamination product in tobacco. Table 2 presents data on carcinogenic volatile *N*-nitrosamines (VNA) in various smokeless tobacco types from the United States, Sweden, and other European countries (Andersen et al., 1989; Brunnemann et al., 1985; Chamberlain et al., 1988; Hoffman et al., 1987; International Agency for Research on Cancer, 1985;

Table 2
Major volatile *N*-nitrosamines in smokeless tobacco, 1981 to 1990

Country	Tobacco Type	Samples (n)	NDMA[a] (μg/kg)	NPYR[a] (μg/kg)	NMOR[a] (μg/kg)
United States	Moist snuff	32	3.8 -215.0	7.4 - 360.0	ND - 690.0
	Dry snuff	3	ND - 19.0	72.0 - 148.0	ND - 39.0
	Chewing tobacco	6	64.0	0.8	0.6
Sweden	Moist snuff	98	0.1 - 50.0	ND - 95.0	ND - 44.0
	Chewing tobacco	4	0.2	0.8	0.4
Norway	Moist snuff	2	130.0	8.9	32.0
Denmark	Chewing tobacco	8	5.5	16.0	ND
United Kingdom	Nasal snuff	5	4.5 - 82.0	1.5 - 130.0	ND
	Moist snuff	7	6.0 - 82.0	64.0 - 860.0	ND - 1.5
Germany	Nasal snuff	7	2.0 - 42.0	5.0 - 75.0	ND

[a] *NDMA, nitrosodimethylamine; NPYR, nitrosopyrrolidine; NMOR, nitrosomorpholine; ND, not detected. Single numbers represent mean of all samples.*

Tricker and Preussmann, 1989). In general, the highest amounts of VNA are found in moist and dry snuff, *N*-nitrosodimethylamine up to 265 ppb and *N*-nitrosopyrrolidine up to 760 ppb. *N*-nitrosomorpholine (NMOR), a strong animal carcinogen, has been detected only in those U.S. snuff brands that were packed in containers lined with a morpholine-containing wax coating (Brunnemann et al., 1982).

Like volatile amines, the amino acids in tobacco, and probably also the proteins with secondary amino groups, are amenable to *N*-nitrosation. Since 1983, numerous studies have reported the presence of nitrosamino acids in smokeless tobacco (Brunnemann et al., 1983; Djordjevic, 1989; Ohshima, 1985; Tricker and Preussmann, 1989 and 1990). Until now, 10 nitrosamino acids have been identified in smokeless tobacco. Of these, nitrosoproline, nitrosothioproline, and iso-NNAC are not carcinogenic; nitrososarcosine, 3-(methylnitrosamino)propionic acid, 4-(methylnitrosamino)butyric acid, and *N*-nitrosoazetadine-2-carboxylic acid are known carcinogens; and the remainder of the identified nitrosamino acids have so far not been bioassayed. (See Table 3.) The concentration of the nitrosamino acids depends on the nitrate or nitrite content of the tobacco as well as on the processing and aging of the tobacco.

TSNA

The most powerful carcinogens in smokeless tobacco derive from the *N*-nitrosation of the *Nicotiana* alkaloids, especially from nicotine and nornico-tine. They are formed during the curing, fermentation, and aging of tobacco. These carcinogens are present in tobacco, tobacco smoke, and

Table 3
Major *N*-nitrosamino acids in smokeless tobacco, 1989 to 1991[a]

Country and Tobacco Type	Samples (n)	NSAR[b] (μg/g)	MNPA[b] (μg/g)	MNBA[b] (μg/g)	NPRO[b] (μg/g)	iso-NNAC[b] (μg/g)
United States						
Moist snuff	10	ND - 2.5	2.2 - 66.0	0.09 - 9.10	1.3 - 60.0	0.05 - 21.00
Chewing tobacco	1	nd	0.6	0.03	0.2	0.01
Dry snuff	3	nd	1.2 - 4.5	0.14 - 0.46	3.0 - 8.1	0.05 - 0.21
Sweden						
Moist snuff	8	0.01 - 0.68	1.0 - 3.3	0.05 - 0.23	0.63 - 8.30	0.04 - 0.11
United Kingdom						
Moist snuff	7	0.03 - 1.10	1.4 - 19.0	0.06 - 8.00	0.33 - 5.00	nd
Nasal snuff	5	ND - 0.04	1.0 - 2.8	0.10 - 0.28	2.7 - 8.7	nd
Germany						
Nasal snuff	7	ND - 0.09	0.49 - 4.30	0.08 - 0.41	0.77 - 7.50	nd

[a] *Adapted from Djordjevic et al., 1989; Hoffmann et al., 1991; Tricker and Preussmann, 1989.*
[b] *NSAR, N-nitrososarcosine; MNPA, 3-(methylnitrosamino)propionic acid; MNBA, 4-(methylnitrosamino)butyric acid; NPRO, N-nitrosoproline; iso-NNAC, 4-(methylnitrosamino)-4-(3-pyridyl)butyric acid; ND, not detected; nd, not determined.*

in environmental tobacco smoke. Of the seven TSNA identified in ST (Figure 3), *N'*-nitrosonornicotine (NNN) and 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone (NNK) are the only known carcinogens in tobacco that induce oral tumors in laboratory animals. *N'*-nitrosoanabasine, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol, and 4-(methylnitrosamino)-4-(3-pyridyl)butanol are carcinogenic in mice or rats (Hoffmann et al., this volume). The high carcinogenic potency and high levels of TSNA have prompted in-depth investigations on the formation and concentration of the alkaloid-derived nitrosamines in the various tobacco products (Table 4). As for the other nitrosamines, the nitrate or nitrite content and the various steps of processing are the determining factors for the yields of carcinogenic TSNA in ST products. According to analytical studies, NNN, nitrosoanabasine, and nitrosoanatabine are formed primarily from the corresponding secondary amines at the early stages of the tobacco processing, whereas TSNA such as NNK are formed from the tertiary amine nicotine (Figure 3) and occur at the later stage of tobacco curing and fermentation (Spiegelhalder and Fisher, 1991). This observation provides a partial explanation of the abundance of TSNA in snuff.

The carcinogenic risk associated with oral ST use and the major contributions of TSNA to this risk are underscored by a number of analytical data. In 1981, the National Research Council estimated the daily exposure of U.S. residents to carcinogenic nitrosamines and found the average nonsmoker is exposed to about 1 μg and the smoker of 20 cigarettes per day to about 11 to 12 μg of carcinogenic nitrosamines (U.S. National Research Council, 1981).

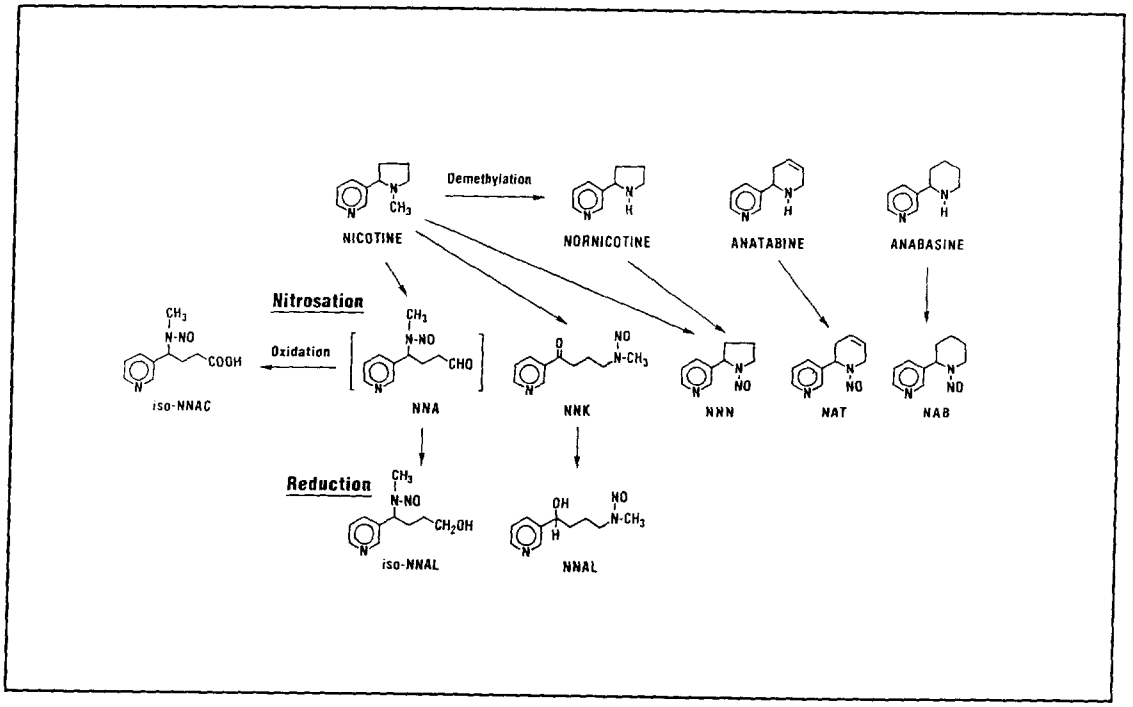
Table 4
TSNA in smokeless tobacco, 1981 to 1989

Country and Tobacco Type	Samples (n)	NNN[a] (μg/g)	NAT[a] (μg/g)	NAB[a] (μg/g)	NNK[a] (μg/g)
United States					
Moist snuff	16	0.83 - 64.00	0.24 - 215.00	0.01 - 6.70	0.08 - 8.30
Chewing tobacco	2	0.67 - 1.50	0.7 - 2.4[b]		0.11 - 0.38
Dry snuff	6	9.4 - 55.0	11 - 40	0.5 - 1.2	0.88 - 14.00
Sweden					
Moist snuff	8	2.0 - 6.1	0.9 - 2.4	0.04 - 0.14	0.61 - 1.70
Canada					
Moist snuff	2	50 - 79	152 - 170	4.0 - 4.8	3.2 - 5.8
Plug	1	2.1	1.7[b]		0.24
Germany					
Plug	2	1.4 - 2.1	0.36 - 0.55[b]		0.03 - 0.04
Nasal snuff	7	2.8 - 19	1.0 - 5.8[a]		0.58 - 6.40
India					
Chewing tobacco	4	0.47 - 0.85	0.40 - 0.50[b]		0.13 - 0.23
Zarda	11	0.40 - 79.00	0.78 - 99[b]		0.22 - 24.00
USSR					
Nass	4	0.12 - 0.52	0.04 - 0.33[b]		0.02 - 0.11
United Kingdom					
Moist snuff	7	1.1 - 52.0	2.0 - 65.0[b]		0.4 - 13.0
Nasal snuff	5	3.0 - 16.0	1.8 - 2.5[b]		0.97 - 4.30

[a] *NNN, N′-nitrosonornicotine; NAT, N′-nitrosoanatabine; NAB, N′-nitrosoanabasine; NNK, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone.*
[b] *Contains NAB.*

On the basis of 1986 data for the two leading U.S. snuff brands, which had about 90 percent of the market share, the average snuff dipper, who consumes snuff at 10 g/d, is exposed to an additional 270 to 280 μg of carcinogenic nitrosamines (Hoffmann et al., 1987). Most of the nitrosamines are extracted from the tobacco during snuff dipping, as is reflected in data from saliva analysis (Hoffmann and Adams, 1981; Nair et al., 1985; Oesterdahl and Slorach, 1988; Paladino et al., 1986; Sipahimalani et al., 1984). In addition, it is strongly indicated that additional amounts of TSNA are endogenously formed during chewing (Nair et al., 1985). Recently we estimated that the average snuff dipper has a lifetime exposure to about 0.70 mmol/kg body weight of NNN and 0.03 mmol/kg body weight of NNK. These levels compare with 1.6 mmol/kg body weight of a mixture of NNN and NNK that induced tumors in the mouths of rats after oral swabbing (Hecht et al., 1986; Hoffmann et al., 1990).

Figure 3
Formation of tobacco-specific *N*-nitrosamines



CONTROL OF CARCINOGENS IN ST

The chemical-analytic data and the results from bioassays and epidemiological studies (Hoffmann et al., this volume; Preston-Martin, 1991; Winn et al., 1981) strongly support the World Health Organization's recommendation that, short of getting people to cease using tobacco, the harmful agents in chewing tobacco and snuff must be reduced (WHO, 1988). The history of the snuff analyses in the United States and Sweden has shown that a drastic reduction of the major carcinogens in ST products is feasible.

In 1981, the U.S. Environmental Protection Agency mandated a ban of maleic hydrazide diethanolamine (MH-30) for use on tobacco (US EPA, 1981). The diethanolamine part of this sucker growth inhibitor gives rise to the carcinogen NDELA (Brunnemann and Hoffmann, 1981). Following the ban of MH-30, the NDELA concentrations in smokeless tobacco declined, as shown by our monitoring of leading brands of snuff and chewing tobaccos. The reduction of NDELA values occurred gradually between 1981 and 1990, from 6,840 ppb to 94 ppb in snuff and from 224 ppb to 74 ppbin chewing tobacco (Brunnemann and Hoffmann, 1991). The concentration of the strongly carcinogenic NMOR in a snuff brand fell from 690 ppb in 1981 to a nondetectable level (< 2 ppb) in 1990 with the elimination of traces of morpholine in the packaging (Brunnemann et al., 1982; Brunnemann and Hoffmann, 1991).

While the reduction or disappearance of NDELA and NMOR was possible through the elimination of their precursors, this approach is not feasible for the reduction of nitrosamino acid and TSNA levels, because proteins and alkaloids, the precursors for these carcinogens, are integral parts of the tobacco. Nevertheless, elimination of nitrate-rich ribs and stems of certain tobacco varieties and changes in ST processing, especially of snuff, can lead to a major reduction of nitrosamines. Using NNN as an indicator for levels of TSNA, we have confirmed its gradual decrease in the two U.S. moist snuff brands that account for more than 85 percent of the current market share. In 1980, we reported 26.5 ppm and 39 ppm of NNN for brands A and B, respectively; in 1990, these levels had decreased to 10.4 and 9.6 ppm, respectively. In Sweden, the average NNN value for the leading five snuff brands in 1980 amounted to 11.4 ppm and in 1990 for three leading brands to 5.4 ppm. Two new snuff brands introduced in 1989 and 1990 on the U.S. market had NNN values of 4.1 and 3.2 ppm, respectively. Because the volatile nitrosamines and the nitrosamino acids are formed during the preparation of snuff by mechanisms similar to those leading to TSNA, their concentrations also have been reduced.

These observations strongly support the concept that product modifications can lead to a significant reduction of nitrosamines in smokeless tobacco (Table 5). Therefore, it was rather surprising that another snuff brand introduced in the United States in 1989 and 1990 contained extremely high concentrations of TSNA and other carcinogenic nitrosamines, in fact the highest ever reported (Table 5; see brand D). The increased pH of this snuff (7.7 to 8.2), compared with other U.S. brands (5.6 to 7.3), suggests that changes in manufacturing were possibly intended to facilitate the absorption of nicotine through the oral mucosa. Unprotonated nicotine, which increases steadily with increased pH above 6.2, is absorbed more rapidly than protonated nicotine (Brunnemann and Hoffmann, 1974; US DHHS, 1988).

The latter finding underscores the WHO recommendation to have the harmful substances in ST subject to governmental control (WHO, 1988), at least as it concerns the United States. Regulating agencies should be encouraged also to evaluate the flavor components and other chemical additives that are used in the manufacture of smokeless tobacco products. Any agents that are teratogenic or genotoxic should be banned.

Table 5
Alkaloids and *N*-nitroso compounds in moist snuff brands, 1990 to 1991[a]

	United States					Sweden
	Brand A	Brand B	Brand C	Brand D[b]	Brand E[c]	Three Brands
Moisture, %	56.0	57.8	51.8	50.00 - 57.8	51.9	46.6 - 54.2
pH	7.11	7.30	5.61	7.72 - 8.17	7.36	7.67 - 7.90
Nicotine, %	2.04	2.17	2.15	1.22 - 2.21	1.47	1.13 - 1.25
Total Alkaloids, %	2.18	2.32	2.32	1.32 - 2.38	1.59	1.24 - 1.41
Volatile Nitrosamines,[d] ng/g						
NDMA	ND[e]	ND[e]	ND[e]	147 - 265	ND[e]	51 - 63
NPYR	44	59	120	245 - 757	ND[e]	ND[g] - 155
Nitrosamino Acids,[f] µg/g						
NSAR	0.06	0.06	ND[g]	0.4 - 2.5	0.10	0.03 - 0.68
MNPA	5.13	3.62	2.72	8.9 - 65.7	2.20	3.10 - 3.23
MNBA	0.47	0.26	0.09	1.9 - 9.1	0.20	0.19 - 0.23
Total	5.70	3.90	2.80	11.2 - 77.3	2.50	3.30 - 4.20
TSNA,[h] µg/g						
NNN	10.40	9.57	4.14	21 - 147	3.20	5.24 - 5.67
NNK	2.19	3.14	1.24	6 - 18	0.70	1.37 - 2.03
NAT + NAB	9.76	7.90	2.97	22 - 115	2.00	2.58 - 3.47
Total	22.30	20.60	8.30	48 - 280	5.90	9.20 - 11.21

[a] *All values are based on dry weight. Total alkaloids include nicotine, nornicotine, mysomine, anatabine, anabasine, 2,3'-dipyridyl, and cotinine.*
[b] *Range of five samples bought in different stores in Texas.*
[c] *Snuff in sachets imported from Sweden.*
[d] *NDMA, N-nitrosodimethylamine; NPYR, N-nitrosopyrrolidine.*
[e] *ND, not detected < 0.005 µg/g.*
[f] *NSAR, N-nitrososarcosine; MNPA, 3-(methylnitrosamino)propionic acid; MNBA, 4-(methylnitrosamino)butyric acid.*
[g] *ND, not detected < 0.01 µg/g.*
[h] *TSNA, tobacco-specific N-nitrosamines; NNN, N'-nitrosonornicotine; NNK, 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone; NAT, N'-nitrosoanatabine; NAB, N'-nitrosoanabasine.*

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