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Selected Constituents in the Smoke of Domestic Low Tar Cigarettes

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Analytical Chemistry Division

Tobacco Smoke Research Program

SELECTED CONSTITUENTS IN THE SMOKE OF DOMESTIC LOW TAR CIGARETTES

W. H. Griest, R. B. Quincy
M. R. Guerin

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ABSTRACT

Thirty-two brands of domestic commercial low tar and nicotine cigarettes were analyzed for their production of tar, nicotine, nitrogen oxides (as nitric oxide), hydrogen cyanide, acrolein, carbon monoxide and carbon dioxide under standard analytical smoking conditions. Results are compared with published data for certain brands.

INTRODUCTION

The Director of the National Cancer Institute Smoking and Health Program has recently reported[1] the practicality of producing "low risk cigarettes" and suggested that a critical number of cigarettes might exist which defines safe smoking practices for each disease state. Safe smoking does not mean hazard-free but rather a smoking practice providing a risk of disease epidemiologically indistinguishable from that for a non-smoker. It is further implied that the "critical number" of cigarettes may be related to the quantity of smoke produced by the cigarette. Tar, nicotine, carbon monoxide, oxides of nitrogen, hydrogen cyanide, and acrolein were chosen as biologically significant constituents of smoke which may serve as markers of smoke production related to various disease states.

Thirty-two brands of domestic commercial cigarettes selected by the Smoking and Health Program management have been analyzed for their production of the marker constituents and carbon dioxide. The data may serve as an input to the computation of critical numbers for currently available name brands.

EXPERIMENTAL

Cigarettes

The cigarette brands were characterized in two sets at time intervals differing by one year. In each set, fresh samples of the brands were purchased locally on the open market, or, in a few cases, obtained from a manufacturer when they were not available in this area. The cartons were stored under deepfreeze (-2°F) in sealed plastic bags. After thawing, the bags and cartons were opened and the cigarettes were conditioned at least 48 hours at 60% ± 2% relative humidity and 24 ± 3.6°C. Cigarettes were selected for analysis by weighing 200 and measuring the resistanceto-draw (RTD) of 100 and choosing those which weighed within ±20 mg of the average and had an RTD within ±10% of the average.

Reference Cigarette

Analytical procedures were periodically tested by application to the smoke generated by the 1R1 Kentucky Reference Cigarette. The deliveries of specific smoke constituents by this cigarette have been measured and documented in previous work.[2]

Smoking

Cigarettes were smoked, four to six per pad, through a standard Cambridge filter assembly[3] on a four port version of the Phipps and Bird Analytical Smoking Machine (Philip Morris design produced by Phipps and Bird, Inc., Richmond, VA) under standard smoking conditions[4] of 35 ± 0.2 ml puff volume, 2 ± 0.2 sec puff duration, and 1 puff/minute frequency to reach a butt length of 23 mm. At least four ports were smoked for each analysis.

Total Particulate Matter (TPM), Water, Nicotine, and Tar [5-7]

Total particulate matter was determined by weighing the material deposited on standard Cambridge Filter pads upon smoking at least four cigarettes per filter. The filter pads were placed in dry dioxane and the extracts analyzed for water and nicotine content by gas chromatography. Tar was computed as the difference between the weights of total particulate matter and nicotine plus water.

Acrolein[8]

The gas phase was collected, puff by puff, on the head of an analytical gas chromatography column maintained at -75°C. When the entire delivery of the cigarette was collected, the column temperature was programmed to separate acrolein from the other components present. A carefully selected reference cigarette was treated identically and the areas of the chromatographic peaks were expressed relative to those in the reference chromatogram. An independently determined calibration factor was used to convert relative delivery of acrolein to absolute units. At least four cigarettes were analyzed.

Oxides of Nitrogen[9]

The gas phase was exhausted into an evacuated flask containing sulfanilic acid, N-(1-Naphthyl)-ethylene diamine dihydrochloride, and glacial acetic acid. After smoking the cigarette, the trapping flask was briefly opened to admit room air and raise the pressure to atmospheric. The flask was shaken for thirty minutes, an aliquot was removed, and oxides of nitrogen were determined spectrophotometrically as nitrite, versus authentic nitrite standards.

Hydrogen Cyanide[10]

Three to five cigarettes were smoked through standard Cambridge filters followed immediately by silica gel traps. The hydrogen cyanide was trapped on the filter pad and on the silica gel. After the hydrogen cyanide was washed free with sodium hydroxide solution it was converted to cyanogen chloride by Chloramine T. A colored complex was formed with pyridine and 1-phenyl-3-methyl-5-pyrazolone. The absorbance of the complex, measured on a spectrophotometer, was related to the amount of hydrogen cyanide through a calibration curve prepared with known standards.

Carbon Monoxide and Carbon Dioxide[11]

The entire gas phase delivery of the cigarette was exhausted into a Saran bag during the smoking for TPM collection. The contents of the bag were analyzed by gas-solid chromatography for carbon monoxide and carbon dioxide.

RESULTS AND DISCUSSION

Results reported here are from analyses carried out in two sets, one in the fall of 1976 and the second in the fall of 1977. In each case, fresh samples of each brand were obtained just prior to the analyses. Table 1 identifies the cigarette brands, carton codes, and smoking parameters of the cigarettes, arranged in two sets according to the date of characterization. Three types of filters could be distinguished visually. *Fact* and *Fact Menthol* employed a resin-loaded filter. The remainder used apparently conventional ventilated filters of two categories. *Kent Golden Lights* (also 100s and Menthol varieties), *Newport Lights Menthol*, and *Old Gold Lights* had air dilution holes arranged lengthwise on the inner paper wrap of the filter. The holes did not extend through the outer wrap. The remainder of the brands contained obvious air dilution holes arranged in circumferential rings on the filter wrap. *Pall Mall* had the type "A" conventional round cross section filter as opposed to the type "B" y-shape partitioned filter.[12]

The results of the analyses are reported in Table 2 for tar, nicotine, carbon monoxide, and carbon dioxide. Table 3 contains data for hydrogen cyanide, oxides of nitrogen, and acrolein. Results are expressed as the average delivery per cigarette and include standard deviations. Per cigarette deliveries of tar range from 14.5 mg to 1.2 mg, with the per cigarette nicotine deliveries ranging from 1.03 mg to 0.14 mg, generally parallel to tar deliveries. Similarly large differences are found for the deliveries of other smoke constituents. Cigarettes with high tar and nicotine deliveries also produced relatively larger amounts of the other constituents. It must be emphasized that the "high delivery"

TABLE 1.

Cigarette and Brand Description

Brand	Carton Code	Cigarette Wt., mg	Cigarette RTD, mm H_2O	Puff Number
I. Set I				
Carlton	DO	795	124.9	6.6
Carlton Menthol	DO	803	113.6	6.6
Fact-Sample No. 1	6 HL	1062	106.8	8.6
Fact-Sample No. 2	6 LX	--	--	--
Fact Menthol-Sample No. 1	6 FB	1008	110.9	8.1
Fact Menthol-Sample No. 2	7 LX	--	--	--
Iceburg 100s	EO	962	144.3	8.6
Kent Golden Lights	R-6	952	83.0	8.4
King Sano	056	1138	140.4	9.1
King Sano Menthol	046	1146	122.6	8.6
Lucky 100s	IO	964	154.3	8.3
Merit	66	1009	134.2	7.8
Merit Menthol	66	1018	140.4	8.2
Now	E2F	794	104.9	7.0
Now Menthol-Sample No. 1	F5	818	104.4	7.6
Now Menthol-Sample No. 2	D2F	812	100.0	7.3
Pall Mall Extra Mild	EO	1015	116.2	8.6
Tempo	1F	1064	155.6	8.9
True	H	854	64.5	7.0
True Menthol	5	884	72.4	7.1
II. Set II				
Benson and Hedges Lights	--	1136	123.3	9.2
Decade	G76	901	91.4	8.1
Decade Menthol	G72	890	101.3	8.1
Kent Golden Lights	H	935	99.7	8.0
Kent Golden Lights Menthol	H	918	90.2	7.3
Kent Golden Lights Deluxe 100s	H	1084	113.3	9.1
Kent Golden Lights Menthol 100s	H	1073	112.6	8.9
L&M Flavor Lights	H7 12	895	97.6	8.2
L&M Long Lights	E7 34	1034	100	9.7
Lark II	E72	837	89.7	8.2
Newport Lights Menthol	W	929	103.4	8.1
Old Gold Lights	W	921	91.6	7.3
Real	ETG	935	113.9	8.1
Real Menthol	FVG	908	106.6	8.1
Stride (Sample 83A)	K77	975	76.2	8.4
Tareyton Lights	MU	1094	119.7	9.6

TABLE 2.

Tar, Nicotine, Carbon Monoxide, and Carbon Dioxide Deliveries of Low Tar and Nicotine Cigarettes

Brand	Tar, mg	Nicotine, mg	Carbon Monoxide, mg	Carbon Dioxide, mg
	Delivery per Cigarette, Mean (mg) ± Std. Deviation (mg)			
I. Set I				
Carlton	1.5 ± 0.085	0.15 ± 0.0096	2.6 ± 0.03	12.5 ± 0.29
Carlton Menthol	1.2 ± 0.036	0.14 ± 0	2.0 ± 0.18	10.2 ± 0.42
Fact	14.5 ± 0.48	1.03 ± 0.022	17.2 ± 0.46	56.9 ± 0.73
Fact Menthol	13.0 ± 1.07	0.98 ± 0.08	15.1 ± 2.8	47.6 ± 6.20
Iceburg 100s	3.1 ± 0.13	0.32 ± 0.0096	5.7 ± 0.60	23.2 ± 1.64
Kent Golden Lights	6.3 ± 0.33	0.62 ± 0.03	6.4 ± 0.17	28.6 ± 0.73
King Sano	5.8 ± 0.36	0.29 ± 0.027	11.6 ± 1.04	40.3 ± 1.09
King Sano Menthol	5.3 ± 0.38	0.25 ± 0.009	13.6 ± 1.04	45.9 ± 2.00
Lucky 100s	3.1 ± 0.23	0.28 ± 0.013	5.3 ± 0.37	21.1 ± 1.46
Merit	8.8 ± 0.37	0.60 ± 0.029	12.1 ± 1.04	42.7 ± 2.55
Merit Menthol	8.4 ± 0.13	0.61 ± 0.044	10.2 ± 1.15	39.6 ± 2.19
Now	1.9 ± 0.17	0.19 ± 0.005	2.4 ± 0.18	11.6 ± 0.95
Now Menthol	1.8 ± 0.31	0.16 ± 0.024	2.1 ± 0.25	11.0 ± 0.80
Pall Mall Extra Mild	5.1 ± 0.33	0.47 ± 0.017	5.8 ± 0.51	25.7 ± 1.64
Tempo	6.9 ± 0.33	0.56 ± 0.021	10.1 ± 0.47	39.0 ± 0.73
True	4.8 ± 0.46	0.46 ± 0.026	5.2 ± 0.40	21.5 ± 0.73
True Menthol	5.2 ± 0.42	0.42 ± 0.033	5.7 ± 0.38	23.5 ± 1.46

TABLE 2. (cont'd)

Tar, Nicotine, Carbon Monoxide, and Carbon Dioxide Deliveries
of Low Tar and Nicotine Cigarettes

Brand	Delivery per Cigarette, Mean (mg) ± Std. Deviation (mg)			
	Tar, mg	Nicotine, mg	Carbon Monoxide, mg	Carbon Dioxide, mg
II. Set II				
Benson and Hedges Lights	10.1 ± 0.44	0.81 ± 0.03	12.1 ± 0.24	40.3 ± 0.89
Decade	5.5 ± 0.45	0.46 ± 0.04	4.3 ± 0.29	19.2 ± 0.89
Decade Menthol	6.6 ± 0.15	0.69 ± 0.02	4.4 ± 0.11	21.8 ± 0.30
Kent Golden Lights	8.9 ± 0.25	0.71 ± 0.01	9.2 ± 0.26	34.4 ± 0.09
Kent Golden Lights Menthol	8.3 ± 0.20	0.66 ± 0.01	8.3 ± 0.11	30.1 ± 0.14
Kent Golden Lights Deluxe 100s	11.6 ± 0.12	0.97 ± 0.03	11.0 ± 0.20	40.8 ± 0.27
Kent Golden Lights Menthol 100s	10.5 ± 0.05	1.00 ± 0.02	11.9 ± .08	41.2 ± 0.09
L&M Flavor Lights	7.2 ± 0.33	0.80 ± 0.10	4.8 ± 0.11	22.3 ± 0.26
L&M Long Lights	6.5 ± 0.27	0.67 ± 0.08	5.5 ± 0.63	22.8 ± 0.26
Lark II	7.5 ± 0.09	0.61 ± 0.01	7.3 ± .08	29.7 ± 0.51
Newport Lights Menthol	10.3 ± 0.40	0.85 ± 0.08	12.5 ± .40	38.0 ± 1.35
Old Gold Lights	11.5 ± 0.5	0.96 ± 0.03	12.5 ± 1.18	37.3 ± 2.75
Real	10.2 ± 0.26	1.01 ± 0.06	12.9 ± 0.22	40.7 ± 0.38
Real Menthol	7.9 ± 0.43	0.81 ± 0.06	10.2 ± 0.47	29.6 ± 0.73
Stride	3.3 ± 0.07	0.36 ± 0.01	1.8 ± 0.05	11.6 ± 0.11
Tareyton Lights	7.8 ± 0.31	0.72 ± 0.01	2.6 ± 0.14	10.7 ± 0.78

TABLE 3.

Hydrogen Cyanide, Oxides of Nitrogen, and Acrolein Deliveries of Low Tar and Nicotine Cigarettes

	Delivery per Cigarette, Mean (μg) ± Std. Deviation (μg)		
Brand	Hydrogen Cyanide, μg	Oxides of Nitrogen (as nitric oxide), μg	Acrolein, μg
I. Set I			
Carlton	16 ± 0.9	34.1 ± 7.0	14.5 ± 1.3
Carlton Menthol	12 ± 1.2	12.0 ± 2.7	9.8 ± 1.0
Fact	147 ± 12.2	233 ± 14.9	108.8 ± 1.5
Fact Menthol	150 ± 10.5	238 ± 24.4	109.2 ± 3.7
Iceburg 100s	44 ± 2.2	43.8 ± 1.8	41.8 ± 1.7
Kent Golden Lights	74 ± 5.5	54.5 ± 7.7	52.3 ± 2.2
King Sano	79 ± 5.1	196 ± 11.3	34.8 ± 5.4
King Sano Menthol	102 ± 3.2	205 ± 5.7	43.5 ± 3.9
Lucky 100s	34 ± 2.6	68.0 ± 0.9	23.0 ± 1.2
Merit	151 ± 6.3	168 ± 11.0	48.5 ± 2.4
Merit Menthol	140 ± 10.5	172 ± 22.6	51.8 ± 1.0
Now	16 ± 2.9	25.2 ± 4.4	15.0 ± 0.8
Now Menthol	9.3 ± 1.2	29.6 ± 5.9	12.5 ± 0.7
Pall Mall Extra Mild	65 ± 5.4	76.0 ± 12.2	37.8 ± 1.7
Tempo	98 ± 3.2	166 ± 5.0	31.0 ± 1.4
True	34 ± 1.4	71.7 ± 14.2	28.8 ± 1.3
True Menthol	43 ± 1.5	63.5 ± 3.6	31.2 ± 1.3

TABLE 3. (cont'd)

Hydrogen Cyanide, Oxides of Nitrogen, and Acrolein Deliveries of Low Tar and Nicotine Cigarettes

Brand	Delivery per Cigarette, Mean (μg) ± Std. Deviation (μg)		
	Hydrogen Cyanide, μg	Oxides of Nitrogen (as nitric oxide), μg	Acrolein, μg
II. Set II			
Benson and Hedges Lights	116. ± 1.4	135 ± 16.1	60.8 ± 1.7
Decade	48.5 ± 7.5	57.0 ± 6.2	37.7 ± 6.4
Decade Menthol	50.4 ± 5.5	61.2 ± 6.2	46.8 ± 1.1
Kent Golden Lights	50.9 ± 2.7	60.8 ± 4.4	47.2 ± 3.5
Kent Golden Lights Menthol	62.1 ± 7.1	71.4 ± 2.3	37.0 ± 3.3
Kent Golden Lights Deluxe 100s	62.2 ± 6.2	83.2 ± 3.8	48.2 ± 2.5
Kent Golden Lights Menthol 100s	70.4 ± 5.8	83.0 ± 8.8	56.8 ± 1.0
L&M Flavor Lights	64.9 ± 8.1	40.2 ± 7.8	29.6 ± 4.5
L&M Long Lights	68.9 ± 5.7	40.8 ± 5.8	46.8 ± 4.4
Lark II	84.2 ± 14.3	82.7 ± 14.2	44.2 ± 0.96
Newport Lights Menthol	133 ± 12.6	85.9 ± 6.0	56.5 ± 5.2
Old Gold Lights	118 ± 8.6	108 ± 7.3	58.2 ± 2.1
Real	155 ± 5.7	98.9 ± 7.2	75.5 ± 4.1
Real Menthol	105 ± 8.2	83.8 ± 11.3	44.0 ± 3.5
Stride	<10	5.3 ± 0.8	11.8 ± 0.5
Tareyton Lights	74.6 ± 0.8	84.6 ± 14.7	31.0 ± 1.8

products considered in this report are lower in delivery than currently most popular products and therefore are still considered "low delivery" products. The lowest tar and nicotine brands, *Carlton, Now Menthol,* and *Stride* were among the lowest in deliveries of carbon monoxide, hydrogen cyanide, oxides of nitrogen, and acrolein of the brands examined here. *Stride* is a new brand being considered for test marketing.

Comparative data are limited. The main body of available data are the Federal Trade Commission tar and nicotine deliveries shown in Table 4. These data are from the latest available report. The two sets of data are in generally good agreement except for *True, True Menthol, Iceburg 100s, Lucky 100s* and *Pall Mall Extra Mild* which were somewhat higher in the Federal Trade Commission (FTC) listings. It should be noted that the FTC data were generated from the analysis of large numbers of cigarettes sampled across the nation, while the ORNL data were obtained from the analysis of two cartons of cigarettes purchased locally. This limited sampling may be partially responsible for the disparity of results.

Table 5 contains "Federal Trade Commission Method" tar and nicotine data found in commercial advertising for some brands not yet included in the official Federal Trade Commission lists. Comparison of these data with the ORNL data in Table 2 shows a fairly good agreement.

Only a very small body of data are available for comparison with the ORNL results on the other smoke constituents considered in this study. Data generated by the F. D. Snell Laboratory and reported in the Readers' Digest[12-13] by W. S. Ross are included in Table 6. The Snell Laboratory carbon monoxide data were converted from ml/cigarette to mg/cigarette assuming 21°C temperature and 760 mm Hg atmospheric pressure at the time

TABLE 4.

Federal Trade Commission
November, 1976 List

Brand	Per Cigarette Delivery Tar, mg	Nicotine, mg
Carlton	1	0.09
Carlton Menthol	0.6	0.05
Fact	14.4	0.98
Fact Menthol	13.0	0.90
Iceburg 100s	8.8	0.63
Kent Golden Lights	8.8	0.65
King Sano	7.2	0.36
King Sano Menthol	7.1	0.33
Lucky 100s	9.1	0.64
Merit	7.9	0.52
Merit Menthol	8.1	0.52
Now	1.5	0.10
Now Menthol	1.4	0.10
Pall Mall Extra Mild	9.7	0.66
Tempo	8.1	0.55
True	15.4	0.38
True Menthol	16.1	0.41

TABLE 5.

"Federal Trade Commission Method" Data from Commercial Advertising

Brand	Tar, mg	Nicotine, mg
Benson and Hedges Lights	11	0.8
Kent Golden Lights	8	0.6
Kent Golden Lights Menthol	8	0.7
Kent Golden Lights 100s	10	0.9
Kent Golden Lights Menthol 100s	10	0.9
L&M Flavor Lights	8	---
L&M Long Lights	8	---
Real	9	0.8
Real Menthol	9	0.8

TABLE 6.

F. D. Snell Laboratory Data[a]

Brand	Per Cigarette Delivery		
	Carbon Monoxide, mg[b]	Hydrogen Cyanide, μg	Oxides of Nitrogen, μg[c]
Fact	13.6	123	175
Kent Golden Lights	8.6	103	114
Merit	9.7	138	185
Now	2.7	35	67
Pall Mall Extra Mild	10.3	128	170

[a]From References 12 and 13.

[b]Calculated from Reference 13 assuming 21°C temperature and 760 mm pressure.

[c]Recalculated as nitric oxide. See Reference 14.

of analysis. Nitrogen oxides expressed as nitrogen dioxide were recalculated as nitric oxide. The latter is the most prevalent form of nitrogen oxides in fresh smoke.[14] The differences between the Snell and ORNL data are greater than the differences between the ORNL and Federal Trade Commission tar and nicotine data. These differences reflect the greater difficulty of measuring gas phase constituents and the absence of well standardized analytical methods for such constituents. Analytical details were not reported with the Snell data. Sensitive, specific procedures are necessary.

An opportunity for a limited comparison of different production batches of several brands was impossible in this study. The data are presented in Table 7 for samples of four brands differing in production batch by 2 months (*Now Menthol*) to approximately one year (*Kent Golden Lights*). Although considerable differences are seen in the deliveries of some constituents--notably tar--no trend as a function of time is apparent. Also, the changes are different for each smoke constituent. It is suggested that subtle changes made in cigarette or filter composition between the production batches may lead to these differences in smoke composition. For example, the resin-loaded filter in the *Fact* varieties may not have been as active in the more recent production batch as in older batches. Thus, hydrogen cyanide deliveries are greater in the newer production batch.

SUMMARY

The deliveries of selected smoke constituents from thirty-two domestic commercial low tar brands have been determined and compared, where possible, with existing data. These data are being employed by the National Cancer Institute Smoking and Health Program to calculate "critical values" of smoking for each brand.

TABLE 7.

Batch-to-Batch Variation in Delivery of Selected Smoke Constituents

Brand	Production Interval	Percentage Change in Per Cigarette Delivery[a]					
		Tar	Nicotine	Carbon Monoxide	Hydrogen Cyanide	Oxides of Nitrogen	Acrolein
Kent Golden Lights	∿1 yr.	+41	+15	+44	+12	-31	-10
Fact Menthol	6 mo.	---	---	---	+42	- 1	+37
Fact	5 mo.	---	---	---	+19	+ 6	+31
Now	2 mo.	+56	+46	---	+18	+32	---

[a]Percentage change in more recent product.

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59. Dr. T. B. Owen, Assistant Director, Smoking and Health Program, National Cancer Institute, Building 31, Room 11A04, Bethesda, MD 20014.

60. Dr. Allen Rodgman, Director of Research, R. J. Reynolds Tobacco Co., Winston-Salem, NC 27102.

61. Dr. Robert Seligman, Philip Morris, Inc., Box 26583, Richmond, VA 23261.

62. Dr. Murray Senkus, Director of Research, R. J. Reynolds Tobacco Co., Winston-Salem, NC 27102.

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65. Dr. T. C. Tso, Chief, Tobacco Laboratory, Beltsville Agricultural Research Service, USDA, Room 104, South Bldg., Beltsville, MD 20705.

66. Dr. Helmut Wakeham, Vice-President, Corporate Research and Development, Philip Morris, Inc., P. O. Box 26583, Richmond, VA 23261.

67. Dr. John Wyatt, Director, Tobacco and Health Research Institute, University of Kentucky, Lexington, KY 40506.

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