The Effect of the Natural Sugar Content of Tobacco Upon the Acetaldehyde Concentration found in Cigarette Smoke*

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INTRODUCTION

Braven et al. (1) have shown that acetaldehyde reacts with cysteine. Fenner and Braven (2) also stated that the smoke from flue-cured tobaccos had a larger effect upon the inactivation of cysteine because the larger sugar content of this type of tobacco is responsible for increasing the acetaldehyde content of tobacco smoke.

In the light of these claims we wish to report work carried out in these laboratories on the yield of acetaldehyde from cigarette smoke and its relationship to the sugar content of the tobacco.

EXPERIMENTAL

Branded cigarettes were not sorted. Experimental cigarettes were made to a constant pressure drop of 6.5–7.5 cm water. All cigarettes were conditioned in atmospheres held at 60% RH and 21° C for at least 48 hours. The cigarettes were smoked at a puff volume of 35 ml for 2 seconds duration, 1 puff per minute. A Phipps and Bird smoking machine was used for the PM (WNF)** deliveries and a Filtrona CSM 10 for the aldehyde determinations. The total volatile aldehydes were determined by a procedure based on the Tobacco Research Council standard method (3). Whole smoke is collected at –80° C and extracted with ethanol. Aldehydes are reacted with 3-methyl-2-benzothiazolone hydrazone hydrochloride and ferric chloride to give a blue colour. Reaction and colour measurements are performed in a Technicon AutoAnalyzer.

Total sugars are estimated by first hydrolysing them with mineral acid at 95° C to give the reducing sugars. These are dialysed, then oxidised with alkaline potassium ferricyanide. The colour loss is measured. Dialysis,

reaction and colour measurements are performed in a Technicon AutoAnalyzer.

RESULTS

The procedure for the determination of total aldehyde delivery measures aliphatic aldehydes, including formaldehyde and acrolein. From a consideration of the aldehyde composition of cigarette smoke vapour phase given by Newsome et al. (5) and the response of this procedure to various aldehydes investigated by Weaving (6), we conclude that 80 to 85 % of the measured total aldehyde delivery is attributable to acetaldehyde alone.

Table 1 gives the yields of smoke aldehydes, PM(WNF) and sugar content of some 40 plain and filter cigarettes sold in the United Kingdom market. The sugar contents of these samples range between 14 and 20 % whilst the total aldehyde deliveries vary between 1173 µg/cigarette and 2444 µg/cigarette. The data in Table 1 were analysed statistically and it was found that neither sugar nor the equilibrium moisture content of the tobacco was related to aldehyde yield. The only relationship found by us was between aldehyde delivery and PM (WNF) yield; this is expressed by the following equation derived from regression analysis:

$$\text{Aldehydes } (\mu\text{g}/\text{ctte.}) = 45.4 \times \text{PM(WNF)} (\text{mg}) + 836.$$

This relationship accounts for 41 % of the total variation between the 40 United Kingdom brands, which are all of the flue-cured tobacco variety.

Table 2 is similar to Table 1 but in this case gives data for brands available in France, West Germany, Belgium, Holland, Italy, Luxembourg, Denmark, Switzerland and Norway. Here the sugar content varies between 1 and 20 % whilst the aldehyde yield varies between 764 µg/cigarette to just less than 2000 µg/cigarette.

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** PM (WNF) = Total particulate matter — (water + nicotine).

Table 1. Total aldehydes deliveries from some major United Kingdom brands*.

Brand	PM (WNF)** mg at 20. 12. 71	Total aldehydes deliveries (µg/ctte.)	Sugar % (dry basis)
1 F	23.3	1718	17.0
2 P	26.2	1726	17.6
3 F	13.0	1451	15.6
4 F	13.7	1353	15.9
5 F	17.8	1552	15.0
6 P	26.0	1857	17.0
7 F	22.1	1437	15.2
8 F	22.6	1698	14.4
9 F	20.8	1400	16.5
10 F	23.3	1328	18.3
11 P	28.3	1965	14.5
12 P	30.6	2418	18.4
13 F	20.7	1837	15.8
14 F	23.9	1739	15.8
15 F	20.3	1627	16.4
16 F	13.1	1564	19.7
17 F	20.5	1550	14.5
18 F	10.3	1173	18.9
19 F	25.5	2444	15.7
20 P	30.5	2217	18.0
21 P	27.8	2450	15.9
22 F	20.3	1616	16.5
23 F	23.1	1998	14.9
24 F	25.0	1861	17.6
25 F	22.8	2300	17.2
26 F	21.6	1922	16.8
27 F	22.7	1823	17.7
28 F	27.9	2298	18.4
29 F	17.0	1789	17.9
30 F	19.4	1740	16.7
31 F	22.3	1870	16.4
32 F	19.3	1806	16.6
33 F	20.8	1932	16.5
34 F	24.1	2308	16.2
35 F	16.5	1969	15.6
36 F	18.3	1923	14.6
37 F	23.5	1690	14.5
38 F	23.8	1924	15.6
39 F	20.5	1771	14.3
40 F	22.2	2323	15.8
41 F	18.8	2444	14.6
42 F	24.1	1550	16.1

* Some 80-85 % of these deliveries are due to acetaldehyde. The cigarettes examined were the varieties currently being produced in November 1971. Newer varieties of some of these brands are currently delivering less total aldehydes due to the use of ventilation techniques etc.

** PM (WNF) = Total particulate matter - (water + nicotine).

F = Filter cigarette P = Plain cigarette

When the data from Continental cigarettes were included in the analyses there was, at first sight, a variation of aldehyde yield with sugar though no relationship with equilibrium moisture. Inspection of the data showed that Italian brands had low sugar and low aldehyde yield, whilst French brands had even lower sugar but higher aldehyde yield.

Table 2.

Cigarette brand	PM (WNF)* (mg)	Total aldehydes delivery (µg/ctte.)	Sugar content of tobacco (% dry basis)
France			
1 F	14.6	1423	1.9
2 P	17.6	1966	1.4
3 F	14.9	1632	1.2
4 P	15.0	1839	11.5
5 P	15.2	1569	1.3
6 F	11.8	1343	1.0
7 F	20.1	1792	20.1
West Germany			
1 F	17.4	1176	12.0
2 F	18.1	1779	14.2
3 F	16.1	1145	15.2
4 F	18.0	1119	12.3
5 F	23.4	1042	11.7
6 F	19.3	1175	13.3
7 P	14.7	1530	9.3
8 F	15.8	764	10.7
9 F	14.7	1335	10.4
Belgium			
1 F	14.8	1633	10.0
2 P	12.8	1644	4.0
3 F	15.5	1658	17.0
Holland			
1 F	16.7	1567	16.7
2 F	13.2	1522	10.1
3 P	14.3	1386	11.9
4 F	13.4	1459	13.0
5 F	12.7	1380	10.8
6 P	16.6	1510	12.5
7 F	13.5	1527	14.6
Italy			
1 P	18.3	943	8.1
2 F	18.4	1009	5.2
3 F	19.4	895	4.3
4 P	18.7	1397	5.4
5 F	19.8	921	4.5
6 P	14.3	1117	2.0
7 F	15.9	1153	10.9
Luxembourg			
1 F	16.1	1352	12.4
Denmark			
1 P	14.8	1600	13.2
2 F	13.9	1653	9.0
3 P	14.3	1455	10.9
4 P	13.4	1226	8.1
Switzerland			
1 F	14.6	964	10.0
Norway			
1 P	15.4	1142	12.0

* PM (WNF) = Total particulate matter - (water + nicotine).

Table 3.

Tobacco type (single grades)	PM (WNF)* (mg)	Total aldehydes delivery (µg/ctte.)	Sugar content (% dry basis)
Sun-cured	41.7	1310	2.8
Fire-cured	40.6	1005	2.9
Air-cured/Burley	24.9	1193	1.8
Flue-cured	31.6	1465	9.2
Flue-cured	28.5	978	16.3
Flue-cured	34.4	1438	28.6

* PM (WNF) = Total particulate matter - (water + nicotine).

It was therefore thought that Italian brands showed this low aldehyde yield because of some other property and not its low sugar content. A separate statistical analysis was made which allowed for differences between the Italian brands and other brands, and it was found that this explained all the differences and no other relationship with sugar content remained. The relationship was shown to be

$$\text{Aldehydes } (\mu\text{g/ctte.}) = 42 \times \text{PM(WNF)} (\text{mg}) + 841$$

for all but the Italian cigarettes and also that

$$\text{Aldehydes } (\mu\text{g/ctte.}) = 42 \times \text{PM(WNF)} (\text{mg}) + 320$$

for Italian cigarettes.

Table 3 lists the values for total aldehyde delivery obtained from plain cigarettes manufactured from single grades of tobacco. It is evident from inspection of the results that there is no correlation between aldehyde and sugar content for these cigarettes.

DISCUSSION

Fenner and Braven (2) claim that cigarettes made from flue-cured tobacco deliver some 50% more acetaldehyde than similar products made from air-cured tobaccos. Furthermore these workers (2) have shown that glucose pyrolysed at between 300–360° C produces significant quantities of acetaldehyde.

It is known that sugar pyrolysed during the smoking process does yield some acetaldehyde but that this is the major source of acetaldehyde is in dispute. Dawson (4) claimed that acetaldehyde is produced at levels below those of carbon monoxide and acetone and that only 2% of the sugar ends up as mixed pyrolysis products.

The results of our experiments show that the total aldehyde yield in smoke is not related to the natural sugar content of the tobacco. It is appreciated that the effects of filtration and weights of tobacco burned have not been taken into account, but with such very large

differences in sugar content between samples it was felt that any relationship that existed would nevertheless show up. To postulate that the yield of acetaldehyde depends on the sugar content would require a hypothesis which could account for a tobacco with 1% sugar yielding an equivalent amount of aldehyde to one with 20% sugar.

The correlation of 41% between PM(WNF) and aldehydes suggests that the aldehydes delivery is largely influenced by such factors as filtration, ventilation and burning rate which normally affect yields of smoke components.

The extrapolation of data obtained in non-smoking experiments neglects such factors and can often give rise to misleading conclusions.

CONCLUSIONS and SUMMARY

All the evidence obtained in our laboratories has shown that the total aldehyde yield in tobacco smoke is not related to either sugar content or the equilibrium moisture content of the tobaccos.

There is, however, a relationship between particulate matter [PM(WNF)]* and aldehyde delivery. This accounts for some 41% of the total variation between different cigarettes.

SCHLUSSFOLGERUNGEN und ZUSAMMENFASSUNG

Auf Grund eigener Experimente weisen die Autoren nach, daß die Ausbeute an Gesamtaldehyden im Tabakrauch weder zu dem Zuckerhalt des Tabaks noch zu dessen Gleichgewichtsfeuchte in Beziehung steht.

Es besteht jedoch eine Beziehung zwischen der Ausbeute an trockenem Rauchkondensat (abzüglich Nikotin) und der an Aldehyden. Hierauf beruhen etwa 41% der gesamten Unterschiede zwischen verschiedenen Cigaretten.

CONCLUSIONS et RESUME

Toutes les preuves qui ont été obtenues dans nos laboratoires montrent que le rendement en aldéhydes totaux dans la fumée de cigarettes est indépendant de la teneur en sucre des tabacs ou de leur humidité d'équilibre.

Il y a par contre une relation entre le condensat sec (moins la nicotine) et la production d'aldéhydes. Ceci représente 41% du total des variations entre les différentes cigarettes.

* PM (WNF) = Total particulate matter - (water + nicotine).

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