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Harmful Components in Tobacco Smoke and Factors Affecting Their Content

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Abstract

The aim of this study was to determine the influence of the smoking regime on the content of tar, nicotine and CO, and to establish the decreasing content of tar, nicotine and CO with increasing the filter ventilation by 10, 20, and 30 %. The smoking regime and filter ventilation were investigated as the factors influencing the components of tobacco smoke. The intensive smoking regimes increased the content of tar, nicotine, and CO between 57 and 164 %. The filter ventilation was the other most significant factor on the increased content of components in tobacco smoke. Tar, nicotine and CO in non-ventilation cigarettes increased between 36 and 92 % compared to the same cigarettes with 30 % ventilation. The greatest increase was observed in intensive smoking regimes and closed ventilation.

Keywords

Tobacco smoke, tar, nicotine, carbon monoxide, smoking regimes, filter ventilation

1 Introduction

Tobacco is a specific product for consumption, used mainly by smoking. Tobacco's use and abuse are linked to nicotine's stimulating and addictive properties.[1] The product of tobacco consumption is tobacco smoke. Except nicotine, more than 5000 chemical components in tobacco smoke have been found. Most of them are carcinogenic, co-carcinogenic, tumorigenic, *etc.*[2,3]

Tobacco smoke is a complex system, composed of mainstream, side stream and environmental tobacco smoke.[4] The WHO study group on tobacco product regulation (TobReg) advised regulating and lowering toxicant yields in cigarette smoke.[5,6]

In the European Union, control of tobacco smoke was regulated in the European Union Directive 2014/40/EU, which sets maximum limits only for tar (10 ± 2 mg/cigarette), nicotine (1 ± 0.2 mg/cigarette) and carbon monoxide (CO) (10 ± 2.5 mg/cigarette), in cigarettes with strictly regulated smoking regime parameters: puff volume, puffs frequency, and puff duration.[7] The smoking under these parameters is known as standard smoking regime or ISO smoking regime and filter ventilation.[8]

The ISO smoking regime is not more representative on actual human smoking behaviour. Scientific studies and international expert deliberations on intensive smoking regimes have been carried out in recent years. These regimes are characterized by an increased puff volume and a number of puffs *per* minute, which is close to the manner of smoking in modern people.[9,10,11]

It is unknown which regime would provide the best characterization for regulation, as none of the smoking regimes represent human behaviour. None is likely to produce data that will be markedly associated with human exposure or risk, either for individual smokers or for population-level differences between products. In fact, the purpose of the testing regimes is mainly to characterise how products perform under a specific set of smoking conditions. The question then turns to how many smoking regimes are required to obtain accurate product characterisation.[12]

The aim of this study was to determine the influence of the smoking regime on the content of tar, nicotine, and CO, and to establish the decreasing content of tar, nicotine, and CO with increasing the filter ventilation by 10, 20 and 30 %.

2 Experimental

2.1 Material

Two types of cigarettes were used:

– CM3 – reference cigarettes with strictly defined physical parameters (length, butts, and non-ventilation) and certified values for tar, nicotine and CO, obtained by standard smoking regime (ISO smoking);
– Industrial cigarette brands: C, D and P, with the same length and butts, but with different filter ventilation.

The description of cigarette samples is shown in Table 1.

Two factors were investigated: smoking regime and filter ventilation. The parameters of the different smoking regimes are presented in Table 2.

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Table 1 – Cigarette types

Cigarettes	
Reference cigarettes	CM3 length: 84 mm; butt – 32 mm; non-ventilation; weight: 0.983 ± 0.003 g; tar: 15.10 ± 1.98 mg/cigarette; nicotine: 1.210 ± 0.216 mg/cigarette
Industrial cigarette brands	C1 length: 84 mm; butt: 33 mm; ventilation: 27 %
	C2 length: 84 mm; butt: 33 mm; ventilation: 37 %
	C3 length: 84 mm; butt: 33 mm; ventilation: 47 %
	D1 length: 84 mm, butt: 33 mm; no ventilation
	D2 length: 84 mm, butt: 33 mm; ventilation: 30 %
	P length: 84 mm; butt: 33 mm; ventilation: 30 %

2.2 Equipment

20-channel smoking machine RM 200A Borgwaldt-kc, Germany,[13] gas chromatograph with flame ionization detector and thermal conductivity detector – GC-FID/TCD, Agilent 7890A.

2.3 Methods

2.3.1 Determination of tar, nicotine and CO (TNCO)

Determination of TNCO in tobacco smoke was conducted according to ISO 4387-2000, ISO 10315-2013 and ISO 8454-2009.[8,14,15] The automatic process of smoking cigarettes was performed on the 20-channel smoking machine according to ISO 3308-2012.[13] The cigarettes were smoked under ISO smoking regime and intensive smoking regime, and the total particulate matter (TPM) as specified in ISO 4387-2000 was collected.[8] Gas chromatograph with flame ionization detector for determination of nicotine and NDIR analyser for determination of CO in tobacco smoke was used.[14,15]

All experiments were performed at least three times. Tar, nicotine and CO yield in tobacco smoke were calculated as mg *per* cigarette. All data were presented as mean ± standard deviation (SD).

3 Results and discussion

3.1 Influence of the smoking regimes on the content of tar, nicotine, and CO

The content of tar, nicotine and CO in reference cigarette CM3 under different smoking regimes is shown in Table 3. The average values of the tar and nicotine for the reference cigarette CM3 smoked under ISO smoking regime corresponded to the certificate content. A good repeatability for tar, nicotine and CO was established, confirming the high accuracy of the reference cigarette and the smoking process.

Table 2 – Parameters of different smoking regimes

Parameters of different smoking regimes	Smoking regime		
	Standard ISO smoking regime	Intensive non-ISO smoking regime	
	(Smoking regime 1)[8]	Massachusetts (Smoking regime 2)[9,11]	Canada (Smoking regime 3)[9,11]
Puff volume / ml	35	45	55
Puff duration / s	2	2	2
Puff frequency / min	1	2	2

It was found that, under intensive smoking regimes (Smoking regimes 2 and 3), the content of tar, nicotine and CO in tobacco smoke had increasing significantly (Table 3).

The data showed that the content of tar and nicotine in Smoking regime 2 had increased by approximately 92–93 % compared to Smoking regime 1, while the CO content increased only by 57 %. The largest increase in tar, nicotine and CO content was observed in Smoking regime 3: 114 %, 112 %, and 75 %, respectively, compared to Smoking regime 1. The data obtained are in accordance with *Coresta*[9] and *Djulancic et al.*[16]

Intensive smoking regimes lead to a higher content in the components of the solid-liquid phase of smoke: tar (91–114 %), wherein lies the main part of the harmful components in tobacco smoke, and nicotine (93–112 %), compared to the gas phase: CO (57–75 %).

Table 3 – Content of tar, nicotine, and CO in tobacco smoke in Reference cigarettes CM3, smoked under standard and intensive smoking regimes

Smoking regime	Tar / mg/cigarette	Nicotine / mg/cigarette	CO / mg/cigarette
Normative value ± standard deviation	15.10 ± 1.98	1.21 ± 0.22	–
Smoking regime 1	13.86 ± 0.24	1.06 ± 0.02	14.90 ± 0.36
Smoking regime 2	26.58 ± 0.30	2.05 ± 0.02	23.40 ± 0.80
Smoking regime 3	29.69 ± 0.50	2.26 ± 0.02	26.12 ± 0.90
Increasing according ISO / %			
Regime 2 *vs.* Regime 1	91	93	57
Regime 3 *vs.* Regime 1	114	112	75

The data obtained was in accordance with other investigations, which found that the increase in the content of tar, nicotine and CO was more than 95 % under intensive smoking regime.[12] *Pauwels et al.*, established that when

Table 4 – Content of tar, nicotine, and CO (mg/cigarette) in tobacco smoke of industrial cigarettes P, smoked under standard and intensive regime Canada, and their normative values

Var.	Smoking regime	Ventilation / %	Tar / mg/cigarette	Nicotine / mg/cigarette	CO / mg/cigarette
I.	Smoking regime 1	30	8.38 ± 0.50	0.73 ± 0.04	9.78 ± 0.60
	Smoking regime 3	30	22.12 ± 1.30	1.88 ± 0.10	20.84 ± 1.40
Increase according to ISO / %			**164**	**156**	**113**
II.	Smoking regime 1	no ventilation	12.15 ± 0.70	0.97 ± 0.05	14.84 ± 0.90
	Smoking regime 3	no ventilation	25.80 ± 1.50	1.99 ± 0.11	26.48 ± 1.70
Increase according to ISO / %			**112**	**106**	**78**
III.	Smoking regime 1	30	8.38 ± 0.80	0.73 ± 0.04	9.78 ± 0.60
	Smoking regime 3	no ventilation	25.80 ± 1.50	1.99 ± 0.11	26.48 ± 1.70
Increase according to ISO / %			**208**	**173**	**171**
Normative value Confidence interval			10.00 ± 2.00 8.00–12.00	1.00 ± 0.20 0.80–1.20	10.00 ± 2.50 7.50–12.50

smoked with a higher puff volume and more frequent puffs using intensive smoking regime, the tar, nicotine and CO yields at least double, compared to ISO smoking regime.[6]

The difference between Smoking regime 1, on the one hand, and Smoking regimes 2 and 3 on the other (puffs volume and puffs frequency), was greater in comparison to the difference between Smoking regime 2 and Smoking regime 3 (only puff volume) – Table 1. Therefore, cigarette brand P was smoked only in Smoking regime 1 and Smoking regime 3, and the content of tar, nicotine and CO was investigated and compared (Table 4).

From the results obtained, it was found that only in Smoking regime 1, with corresponding ventilation, Var. I, the tar, nicotine and CO content corresponded to the regulatory requirements of the Directive 40/2014. The Smoking regime 3 led to a significant increase in the content of tar, nicotine and CO in both versions: open ventilation (Var. I) and non-ventilation (Var. II). This increase was most pronounced when comparing the results of intensive smoking with taping ventilation and standard smoking with open ventilation (Var. III). These are the optimal smoking parameters in the Intensive smoking regime currently validated in TobLabNet.

Therefore, if steps are taken in the future to regulate the intensive regime such as Canadian method (Smoking regime 3), the majority of cigarette brands to which a similar method is used to measure the content of tar, nicotine, and CO in tobacco smoke will not meet the norms and will breach the limits of the European Union Directive 2014/40/EU.[7]

3.2 Influence of the filter ventilation on the content of TNCO

In the European Union, according to Directive 40/2014, a maximum machine-measured tar, nicotine and CO yield is mandated for all cigarettes, attributable to the belief that lower tar, nicotine and CO yields lead to safer cigarettes, which happens to be achieved primarily through the use of filter ventilation. Filter ventilation is a major design feature, which is used by cigarette industry, for cigarettes with similar tobacco blends and similar designs to have lower smoking machine tar yields resulting in reduced yields of tar, nicotine, and CO.[17,18] Filter ventilation is the percentage of smoke that is diluted by air when a smoker takes a puff.

Table 5 – Influence of the filter ventilation on the content of tar, nicotine, and CO in tobacco smoke in the industrial cigarette brands, smoked under Smoking regime 1

Sample cigarette	Ventilation / %	Tar / mg/cigarette	Nicotine / mg/cigarette	CO / mg/cigarette
C1	27 %	10.7 ± 0.60	1.20 ± 0.07	12.0 ± 0.70
C2	37 %↑	9.10 ± 0.50 ↓	0.86 ± 0.05↓	9.80 ± 0.60 ↓
C3	47 %↑	6.70 ± 0.39↓	0.68 ± 0.04↓	6.40 ± 0.40↓
D1	Non-vent.	10.60 ± 0.60	1.04 ± 0.06	15.60 ± 1.00
D2	30 %↑↑	5.50 ± 0.32↓↓	0.76 ± 0.04↓↓	8.70 ± 0.60↓↓

The content of tar, nicotine and CO in tobacco smoke of two industrially manufactured cigarettes C and D was investigated (Table 5). The cigarettes of each sample had the same physical parameters: length of cigarette and length of butts, but differed in filter ventilation (Table 1). The ventilation of sample C varied between 27 and 47 %, while the sample D differed between 0 and 30 % filter ventilation. Cigarettes were tested under Smoking regime 1 (ISO regime).

Table 5 shows that with increasing ventilation rates (from 27 to 47 % sample C), the content of tar, nicotine and CO decreased. Particularly significant was the difference in sample D, where the difference in filter ventilation was

greater (non-ventilation and 30 % ventilation). The content of tar and CO in sample D1 increased by about 92 %, while in nicotine content by 36 % compared to sample D2. The results obtained were in accordance with the studies of *Pauwels et al.,* where the yields of tar increased between 18 and 939 %, nicotine yields between 0 and 148 % and CO between 32 and 731 % (ISO/filter ventilation *vs* ISO-non filter ventilation).[6]

4 Conclusion

The influence of factors such as smoking regime and filter ventilation, on the content of tar, nicotine and CO in tobacco smoke was investigated. The content of tar, nicotine and CO increased between 57 and 93 % under Smoking regime 2 and between 75 and 114 % under Smoking regime 3, compared to the standard Smoking regime (ISO method). The greatest increase was detected in nicotine content, while the tar and CO increase was less. The content of tar, nicotine and CO under intensive smoking regime exceeded the maximum permitted in EU, and was not in accordance with the regulatory requirements under intensive smoking regime. The filter ventilation was the most significant factor on the content of tobacco smoke. In non-ventilated cigarettes, the tar, nicotine and CO content increased between 36 and 92 % compared to the same cigarettes with 30 % ventilation. If Canadian method (Smoking regime 3) replaced ISO method in the European Union Directive 2014/40/EU, the content of tar, nicotine and CO in the majority of cigarette brands will breach the levels of Directive.

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SAŽETAK

Štetne tvari u duhanskom dimu i čimbenici koji utječu na njihov sadržaj

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Cilj ovog istraživanja bio je utvrditi utjecaj režima pušenja na sadržaj katrana, nikotina i ugljikova monoksida (CO) u dimu cigareta te utvrditi dolazi li do smanjenja njihova sadržaja uslijed povećanja ventiliranosti filtra za 10, 20 i 30 %. Režim pušenja i ventiliranost filtra istraživani su kao čimbenici koji utječu na komponente dima. Intenzivni režimi pušenja povećali su sadržaj katrana, nikotina i CO u dimu između 57 i 164 %. Ventiliranost filtra drugi je najznačajniji čimbenik povećanog sadržaja komponenti u duhanskom dimu. Katran, nikotin i CO u cigaretama bez ventiliranog filtra povećali su se između 36 i 92 % u usporedbi s istim cigaretama koje su imale 30 %-tnu ventiliranost. Najveći porast zabilježen je u režimima intenzivnog pušenja i bez ventilacije.

Ključne riječi
Duhanski dim, katran, nikotin, ugljikov monoksid, režimi pušenja, ventiliranost filtra

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