Tutun/Tobacco, Vol.62, N^{O} 7-12, 265-271, 2012

ISSN 0494-3244

UDC:663.97.057
Original scientific paper

INVESTIGATION OF EFFICIENCY OF CIGARETTE PAPER FILTERS

Stefka Kirkova[1], Marija Srbinoska[2*], Nataša Zdraveska[2]

[1]Tobacco and Tobacco Products Institute, Plovdiv, Republic of Bulgaria
[2]Scientific Tobacco Institute-Prilep, Republic of Macedonia
srbinoska.marija@yahoo.com

ABSTRACT

Filter design and materials is a major tool to modify the filtration efficiency for cigarette smoke.Despite the variety of filters in the market, cellulose acetatecontinued to be most common used filter in cigarettes. Filters within a similar smoke removal efficiency range are also manufactured from paper. It is estimated that in recent yearsthe productionof cellulose acetate tow willbelessthanthe demand forcellulosefilters.
The aim of our research is to determine the efficiency of paper filter rod on the smoke composition and retention of particulate matter and nicotine compared to the cellulose acetate filter rod, as control. The content of tar and nicotine were measured according to ISO 4387 and ISO 10315,respectivelly. For certifying the pressure drop of the filter rod and cigarette was used ISO 6565:2011. The results have shown that removal efficiency of paper filter was comparable to cellulose acetate filter.

Key words: paper, cellulose acetate, filter rod, efficiency, particular matter, nicotine, smoke

ИСТРАЖУВАЊЕ НА ЕФИКАСНОСТА НА ХАРИЕНИТЕ ФИЛТРИ ЗА ЦИГАРИ

Дизајнот и материјалите кои се користат за изработка на филтер-стапчетосе главна алатка за модифицирање на ефикасноста на филтрирањето на чадот од цигарите. И покрај широкиот спектар на цигарни филтер-стапчиња на пазарот, ацетатното продолжи да биде најчесто користено филтер-стапче. Со слична ефикасност за отстранување чадот е филтер-стапчетоизработено од хартија. Се проценува дека во последниве години производство на целулозно ацетатни филаментиуспоруваи ќе биде помало од побарувачката на ацетатно целулозните филтри. Целта на нашето истражување е да се утврди ефикасноста на хартиеното филтер–стапче врз составот на чадот и на задржувањето на цврстите честички и никотинот во споредба со филтер-стапчето од целулоза ацетат како контрола. Содржината на катранот и никотинот се одредува според ISO 4387 и ISO 10315, последователно. За сертифицирање на падот на притисок на филтер-стачето и цигари беше употребен ISO 6565. Резултатите покажаа дека ефикасноста на отстранување на хартиеното филтер–стапче е споредлива софилтер-стапчето од целулоза ацетат.

Клучни зборови: хартиено, целулозно ацетатно, филтер-стапче, ефикасност, цврсти честички, никотин, чад

INTRODUCTION

Cigarettes marketed today may be perceived as havingessentially two sections—a column of tobacco and a filter. Large-scale manufacture of filtered cigarettes began in the early 1950s in response to demand for lower smoke yields. The purpose of the first filters on cigarettes was primarily to aesthetic and hygienic function. Gradually, this function shifts and filters nowadays are regarded as a major modifier of tobacco smoke.Filtered cigarettes gained popularity rapidly, and today the majority of cigarettes sold are filtered.Moreover, even tobacco for rolling cigarettes available for consumption with filter cartridges with slices. Because filter materials influence yields of some smoke constituents to varying degrees, cigarette taste changes with the filter material used (Kirkova, 2007, 2007a).

Probably the first functioning filters were made from creped paper that was corrugated and formed into a cylinder. These filters were and are efficient smoke removers, but they were rapidly replaced by cellulose acetate filters when they became available (Browne,1990, Norman, 1999).

For most of the world, the primary cigarette filter medium is cellulose acetate, with a smaller specialty market primarily using dual or triple filters containing cellulose acetate with corrugated paper and/or activated charcoal (Norman, 1999, Georgiev, 2002, Nikolić, 2004).

The filter—whether made of cellulose acetate tow, paper, or a combination of these—serves several purposes. Functionally, it reduces the amount of smoke, captures particulate matter from the smoke and absorbs vapours. Particulate removal occurs largely through mechanical filtration of the smoke aerosol particles. Smoke particles can be captured via internal impaction, diffusion or direct interception. About 65% of the total particulate removal is attributed to diffusional deposition, and 35% to direct interception (Eaker, 1990, Georgiev, 2002).

Cellulose acetate and paper filter materials have only small influences on vapour phase retention (Browne,1990, Hoffmannet al., 1995, Norman, 1999).

Factors that influence preferential retention include several properties of both the compounds of interests (particulate matter, semivolatile, volatile, carbon monoxide) and of the fiber (Georgiev, 2002, Nikolić, 2004, Kirkova, 2004, 2004a).

By estimates, however, consumption of acetate filament as the main raw material for production of filter rods in the coming years will exceed supply. In this regard, many companies have directed their efforts to develop advanced technologies for production of filter material from non-traditional and readily available materials.

The problem with these developments is to maintain and/or increase the attenuation of the filters with minimum modifying effect, and preservation of the smoking characteristics typical for the brand. For this reason of particular interest are paper filters. The aim of our research is to determine what is the efficiency of the paper filter from the known and preferred efficiency of cellulose acetate filter.

MATERIAL AND METHODS

The object of our research are filter rods made of acetate filament 3.0 Y35 000-control and made of a special corrugated paper-test sample.

Experiments were performed on paper sheet with two width and varying depths of longitudinally corrugating. Filter rods used have different paper width - 300 mm and 330 mm and depth of corrugating from 0.00 mm to 0.50 mm. Final length of filter rod was 126 mm.

To determine the retention efficiency of the filters cigarettes were made on same cigarette making machine (Molins 9N, UK). The filter rod was 20 mm long and the length of the cork-paper was 24mm. The total cigarette length was 84 mm.

Using standardized methods for analysis we determine the physical properties of the filter rods (corrugation depth, diameter, mass, pressure drop and hardness) and thickness of tipping paper. Used tipping papers used in both filters were no perforated, and with very close valuesof their masses. Cigarette paper and wrapping paper are regular manufactured.

Determination of cigarette mass, resistance to draw, cigarettes diameter, hardness and statistical processing of the results were made on SODIMAT.

Cigarettes are smoked under standard conditions, the cigarette smoke condensate collected on a Cambridge filter pad as described in ISO 4387:2000, and vapor phase for determination of carbon monoxide in ISO 8454:2007. This condensate is extracted as per nicotine determination described in ISO 10315:2000. The number of puffs in control and test samples was equal. It follows that for both cigarettes (control and test samples) are provided with equal conditions of combustion, which provides uniformity of the smoking parameters.

RESULTS AND DISCUSSION

1.Characterization of paper physical properties

Values of the most important physical parameters of paper filter rods investigated in this experiment (corrugation depth, diameter, mass, pressure drop and hardness) and the coefficient of variation (CV) were presented in Tables 1.

Table 1. Physical parameters of paper filter rods

Paper width 300 mm							
Corrugation depth (%)	Diameter (mm)	Weight (g)	Pressure drop (mm WG)			Hardness (%)	
			L=126 mm	CV	L=20 mm	%	CV
0.00	7.84	1.10	362.4	3.0	57.5	92.6	0.9
0.10	7.87	1.09	434.2	1.9	68.9	92.5	0.8
0.20	7.84	1.09	485.0	2.1	77.0	93.2	0.7
0.30	7.85	1.10	573.1	2.2	91.0	95.1	1.1
Paper width 330 mm							
0.10	7.86	1.20	627.3	2.2	99.6	95.0	1.0
0.50	7.87	1.19	736.8	2.4	117.0	95.7	1.3

The results show that with increasing width of the paper increases pressure drop and hardness of filter rods at a relatively constant weight and diameter. The coefficient of variation also is increased. It is obvious that with increasing depth of corrugating increasing values of pressure drop and hardness. This is explained by the increase of specific surface of filter. Compared with acetate filters, variation in pressure drop for the same amount is significantly higher, which means higher possibility to adjust the efficiency for smoke filtering. Increase the depth of corrugating gives proportionally increasing values of pressure drop and strength.

The coefficient of variation was biggest at depth of flute of 2.40 mm. Acceptable values for pressure drop, hardness and coefficient of variation are obtained at a depth of flute of 0.2 mm. Therefore, further research continued with the paper width 300 mm and depth of flute of 0.2 mm.

2. Comparison of the physical properties of the control and test sample filter rod

In Table 2 were present the mean values of average performance on the test filter rods of acetate filament - control and paper – sample, both both with a length of 120 mm.

Table 2. Comparison of parameter between paper and cellulose acetate filters

Properties	Cellulose acetate			Paper		
	м	y	CV	м	y	CV
Weight (g)	0.774	7.1	0.92	1.143	8.6	0.76
Pressure drop (mm)	367	86	249	345	15.9	4.95
Diameter (mm)	7.86	0.03	0.35	7.86	0.02	0.22
Hardness (%)	84.36	-	-	89,49	-	-
Weight (mm)	0.041	1.957	4.77	0.042	1.342	3.23

Compared with acetate filter, paper filter have a higher weight. The fact that the paper filter had higher weight due to the higher specific surface area, allows higher removal efficiency. Subsequently and hardness values are higher in the paper filter. It is noteworthy that the pressure drop was slightly reduced. The remaining results are similar to the values obtained for acetate filter.

3. Retention of particulate matter and nicotine

The primary effect of fibrous cigarette filters (paper or cellulose acetate) is removal of particulate from the smoke. The major mechanism of smoke retention in fibrous cigarette filters is mechanical capture of aerosol particles. The nicotine removal is dependent on particulate filtration. In general, cellulose acetate remove tar and nicotine particles in this size range with an efficiency of 40-50% (Norman, 1999). According to Georgiev, (2002) paper filters without additives are characterized by medium efficiency for retention of nicotine and condensate (30% and 40%, respectively).

In Tables 3 are summarized values of the most important physical parameters on cigarettes with cellulose acetate and paper filters.

Table 3. Physical parameters of investigated cigarette and filter

Parameter	Cellulose acetate	Paper
Average cigarette weight (g)	103.39	111.12
Cigarette weight (g)	1.020-1.040	1.090-1.110
Filter weight (g)	0.147	0.213
Other materials weight (g)	0.197	0.263
Draw resistance of cigarette (mmWG)	99-104	103-104
Pressure drop of filter (mmWG)	61.30	68.85
Diameter of cigarette (mm)	7.96-7.98	7.96-7.98
Hardness of cigarette (%)	78.54	77.89
Length of cigarette (mm)	84.42	84.26
Length of filter (mm)	19.94	20.13

It was found that cigarettes with paper filter shown the higher retention for nicotine and tar in comparison to acetate. Retention efficiency ranged from 12.1% higher for nicotine to 8.19% higher for particulate matter (Table 4).

Table 4. Comparison of retention between paper and cellulose acetate filters

Retention (%)		Particulate matter	Nicotine
Cellulose acetate	A	42.42	39.68
	B	43.30	37.91
	Mean value	42.86	38.79
Paper	A	52.50	51.18
	B	49.60	50.59
	Mean value	51.05	50.89

Obtained results are graphically presented on Figure 1.

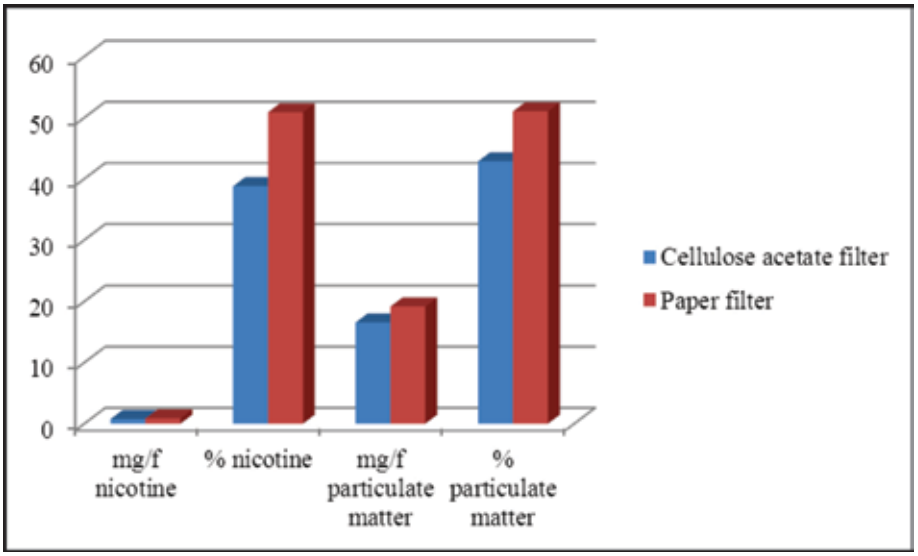

Figure 1. Retention efficiency of paper and cellulose acetate filter

4. **Removal efficiency of paper and cellulose acetate filters for particulate matter, nicotine and carbon monoxide from mainstream smoke**

In Tables 5 were presented values of the physical parameters on cigarettes with cellulose acetate and with paper filter.

Table 5. Physical parameters of cigarettes and filter rods

Parameter	Cellulose acetate	Paper
Cigarette weight (g)	1.030	1.110
Tobacco weight (g)	0.840	0.845
Other materials weight (g)	0.197	0.263
Cigarette length (mm)	84.0	84.0
Filter length (mm)	20.0	20.0
Diameter (mm)	7.95	7.95
Draw resistance of cigarette (mmWG)	102	105
Pressure drop of filter (mmWG)	62	68
Hardness of cigarette (%)	78.5	77.9
Permeability (CU)	35.0	35.2
Free combustion (mm)	10.3	10.4

The results show the increase in weight of cigarettes with relatively equal weight of tobacco. It results because the weight of other materials in cigarette was bigger. Cigarettes were analyzed to determine the amount of nicotine, carbon monoxide and total particulate matter in mainstream smoke.

Obtained results are graphically presented on Figure 2.

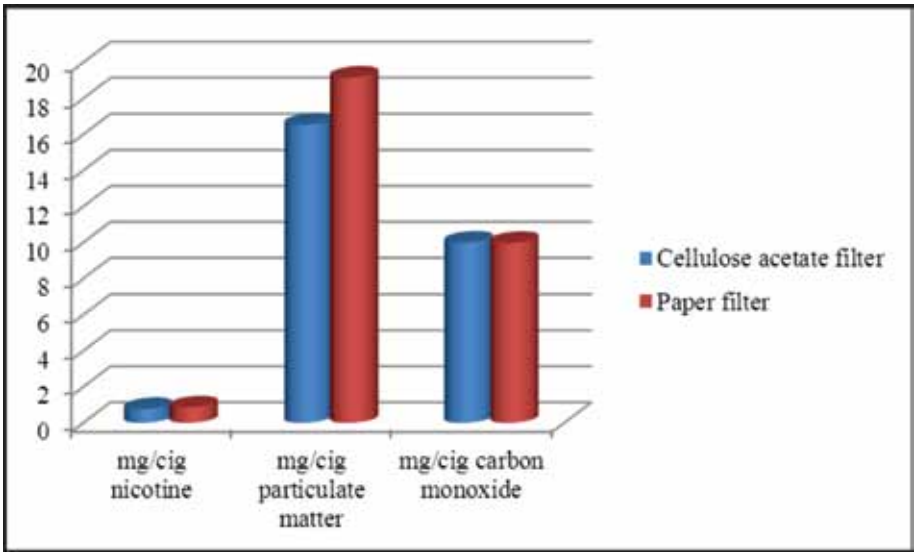

Figure 2. Chemical composition of cigarettes with paper and cellulose acetate filter

From the results it can be concluded that although it uses the same tobacco blend and uniform design cigarettes, nicotine in cigarette with paper filter was lower by 0.3 mg/cig, or 26.50% than cigarette with acetate filter. Also, particulate matter in cigarette with paper filter was lower by 3.71 mg/cig, or 16.80% than cigarette with acetate filter, as control. As regards the retention of carbon monoxide both filters have the same capacity.

CONCLUSION

The results of this study demonstrate the possibilities of paper filters and their effectiveness against the harmful constituents of smoke - nicotine and particulate matter, while preserving the smoking characteristics of cigarettes.

Investigated paper filter is characterized by high efficiency for retention of nicotine and particulate matter from mainstream smoke. Both type of filters, paper and cellulose acetate have only small influences on carbon monoxide retention.

REFERENCES

1. Browne C.L., 1990. The design of cigarettes, 3rd ed: Hoechst Celanese, 59-89.
2. Eaker D.W., 1990. Dynamic behaviour and filtration of mainstram smoke in the tobacco column and filter. Rec.Adv.Tob. Sci16.103-187.
3. Hoffmann D., Djordjevic M.V., Brunnemann K.D., 1995.Changes in cigarette design and composition over time and how they influence the yields of smoke constituents. J SmokingRelated Disorders; 6:9–23.
4. ISO 10315:2000 Cigarettes -- Determination of nicotine in smoke condensates -- Gas-chromatographic method.
5. ISO 4387:2000 Determination of Total and Nicotine-Free Dry Particulate Matter using a Routine Analytical Cigarette-Smoking Machine Determination of Total Particulate Matter and Preparation for Water and Nicotine Measurements.
6. ISO 6565:2011 Tobacco and tobacco products -- Draw resistance of cigarettes and pressure drop of filter rods -- Standard conditions and measurement.
7. ISO 8454:2007 Cigarettes -- Determination of carbon monoxide in the vapour phase of cigarette smoke -- NDIR method.
8. Kirkova, S., 2004. Studies on the influence of some factors in lowering the levels of nicotine, tar and carbon monoxide in cigarette smoke, 15th National Conference with International Participation "Quality-for better life'2004", 113-118.
9. Kirkova, S., 2004a.Study the interdependence between the content of nicotine, tar and carbon monoxide in cigarette smoke, Scientific conference with international participation "in '60 ITTI" of HT ITTI, 345-350.
10. Kirkova, S., 2007. Studies on the interdependence of nicotine, tar and carbon monoxide in cigarette smoke and its manageability, Scientific conference with international participation "Food Science and Technology 2007", UFT, HT-LIV, Iss.1, 243-246.
11. Kirkova, S., 2007a. Studies on the design element of tobacco to reduce nicotine, tar and carbon monoxide in smoke Scientific conference with international participation "Food Science and Technology 2007", UFT, HT-LIV, Iss. 1, 253-257.
12. Nikolić M., 2004. Tehnologija prerade duvana, Univerzitet u Beogradu, Poljoprivredni fakultet, 73-83.
13. Norman A., 1999. Cigarette design and materials, in Davis D. L, Tobacco Production, Chemistry and Technology, 346-352.
14. Георгиев С. 2002. Технология на тютюневите изделия, второ издание, Антоан Георгиев, Пловдив, 270-326.