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Effect of cigarette filter components on its efficiency and smoking characteristics of cigarettes

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The study was aimed to evaluate the cigarette filter characteristics i.e. ventilation, pressure drop and retention of tar and nicotine as affected by components used. The improvement of filter characteristics as well as smoking characteristics of cigarette as affected by improved cigarette filter was also endured. Cellulose acetate at 210 mg, tipping paper rows (1, 2 and 4) and pressure drop were studied compared to the applied parameters. It was found an increase in nicotine and tar retention from 44.61 to 48.46, 59.23 and 62.31%, and! 48.87 to 51.54, 64.31 and 70.14%, respectively. Ventilation was also increased from 11.13 to 18.89, 49.23 and 53.46%. While a decrease in pressure drop of cigarette from 135 to 126, 103 and 83 mmWG. The smoking characteristics of cigarettes were as indicated by sensory evaluation and the modified sample had almost the total acceptable (72) as for the imported foreign samples (72, 72, 74 and 72). But the modified sample by using 200 mg cellulose acetate, tipping paper 2 rows, filter of paper 8000 CU had high consumer acceptance (72) and almost the same as foreign samples (72, 72, 74 and 72). In addition it had the same cost as the already processed cigarettes.

Keywords: Nicotine, tar, ventilation, smoking, Pressure drop and cigarette filter.

INTRODUCTION

The efficiency of cellulose acetate filters total particulate matters (TPM) removal could be increased by reducing the diameter of the filaments without increasing the pressure drop or by using a longer filter tip. The conventional cigarettes filter was accepted to consumers with a maximum pressure drop up to about 130 mm water column (Kiefer and Touey, 1967).

Conventional cellulose acetate had the capability to selectively reduce some of the volatile and semi volatile compounds in the smoke stream, especially when the filter was treated with certain plasticizers, such as glycerol triacetate (George *et al.*, 1967).

The most effective means of reducing gas-phase components in smoke was the use of porous cigarette papers and ventilated filters (Baker, 1984).

Since 1955 the U.S. weighted average tar and nicotine in cigarettes were reduced from 38 mg to 12 mg and 2.7 mg to 0.95 mg, respectively. A major reason for the decrease in smoke yields was acceptance of cigarette filter used. The filter was increased used in cigarette production in America from 0.56% to 19% in 1955, while it was 51%, 82% and 92% in 1960, 1970 and 1980, respectively, and more than 97% since 1993 (Hoffmann et al., 1994).

Tobacco companies responded to the growing public concern over the health effects of smoking by heavily promoting new types of cigarettes, such as cigarettes with filters in the 1950s and "low-tar" cigarettes started in the mid-1960s (Stanton et al, 1998).

In the UK the development of lower tar cigarettes has been undertaken in association with various government bodies. It has been accomplished by

the use of filters and filter ventilation, modified cigarette paper and modified forms of tobacco and tobacco blends. In the UK the sales-weighted average ‘‘tar’’ yield has been gradually reduced from about 38mg in the mid-1950s to below 10mg today (ISO 3308, 2000)

The Cigarette filters were specifically designed to absorb vapors and to accumulate particulate smoke components (Kathleen, 2000).

The basic principle of ventilation was to allow fresh air to enter laterally into the cigarette and to mix with smoke while the puff was drawn (ISO 9512, 2002).

Filter ventilation allows for the cigarette yields to be “elastic” when smoked by smokers. Increased puffing intensity resulted in a nonlinear increase in the concentration of tar and nicotine yields because ventilation and tar reduction depend on how fast and large the puff (Hammond *et al.*, 2005).

Reductions in tar levels to meet the newly adopted on 15 mg tar yield have primarily been achieved through design modification, most prominently increasing filter ventilation (Hammond *et al.*, 2006).

Increasing ventilation levels decreased the smoke flow rate through the filter, which, in turn, increased smoke residence time within the rod and allowed greater opportunity for gaseous diffusion to occur. In contrast, the reduced flow rate entails increased filter efficiency for particulate matter ‘tar’ (Baker, 2006).

Filter ventilation was used in about 7% of marketed cigarettes by the end of the 1960s, but rapidly increased from 94% to 100% by 1982(Kozlowski *et al*., 2006).

Cigarette filter ventilation rate and number of puff strongly influenced the yield of cigarette smoke. Higher ventilated cigarettes lead to lower absolute yields but also to a higher degree of incomplete combustion (Adam *et al*., 2010).

Filter ventilation increased particle size in the smoke due to increased water content, condensation, and coagulation as the smoke passes through the tobacco rod. This is due to the slower burn down of the cigarette and increased residence time of the smoke, allowing for the particles to absorb more water and constituent gases (Kane et al, 2010).

Cigarette filter ventilation is closely associated with machine measured tar yield and is generally higher in brands previously marketed as ‘Light’. (Connolly *et al*., 2014).

The design of cigarette filter ventilation was already affect nicotine yield (Land et al., 2014).

Today, the percentage of filter ventilation used in commercial cigarettes ranges from 0% to 83%, although most smokers choose cigarettes that have 10% to 20% ventilation (10–15mg tar yield). A small number of smokers prefer cigarettes with greater than 40% ventilation (1–6mg tar yields) (Pazo *et al*., 2016).

Cigarette filter characteristics are mainly affected by its components (denier, CU of paper and the mmWG of pressure drop)

The denier of cellulose acetate (a unit of measure for the linear mass density of fibers, and defined as the mass in grams per 9000 meters of the fiber (Haynes, Williams, 1946)). **The CU of the tipping paper and cigarette filter paper** (CU = CORESTA unit, is defined as the volume of air in cm^3 min^{-1} that will flow through a $1cm^2$ orifice at a pressure drop of 1kPa (ISO 2965, 2009), tipping paper is the paper used to assemble the cigarette filter with the tobacco rod and it contains holes to increase cigarettes ventilation). **The mmWG pressure drop of the cigarette filter** (mmWG = Millimeters water gauge. It is the pressure required to support a water column of the specified height, mmWG = 9.80665 Pascal, this unit is used in measurement of pressure drop).

The present work was aimed to study the effect of cigarette filter components on its characteristics. Moreover, the effect of these changes on smoking characteristics of cigarette was also evaluated.

MATERIALS AND METHODS

MATERIALS:

Cellulose acetate (Rhodia Co., Germany), Plug wrap paper of filter (Gltz Co., Germany), Hot melt (HB fuller Co., Portugal), Polyvinyl acetate (Ashwa tech. Co., Egypt) and Triacetine plasticizer (Jiangsu lemon chemical and technology Co., China) were used.

The solvents isopropanol, heptadecane and ethanol (Sigma Chemical Co., St., Louis, USA) were also used.

Processing of cigarette filter:

Cigarette filter was processed according to James and Winston, 1985 as follows:

The ingredients used in cigarette filter were 81.60% cellulose acetate 3y35000 denier, inner paper 10.18 % 4000 CU, plasticizer 7.4%, hot melt (outer glue) 0.48% and polyvinyl acetate (inner glue) 0.34%. The cigarette filter were production by KFF2 filter machines (Hauni Co.,

Germany), at Eastern Company, 6 October City, Egypt.

The same procedure previously mentioned was used in the following 4 experiments (treatments) with slight modifications:

1. Cellulose acetate was increased from 200 mg/cigarette to 210 mg/cigarette.
2. Tipping paper at different rows (1, 2 and 4) and at different number of holes were evaluated.
3. The pressure drop of filter was increased from 58 mmWG to 67 and 68 mmWG.
4. Filter paper of 8000 CU was used instead of 4000 CU and also tipping paper at1, 2 and 4 rows were used.

At each rows (1, 2 and 4) the number of holes and diameter were calculated 1 row (content 20 holes / cm with diameter 0.14 mm).

2 rows (content 40 holes / cm with diameter 0.14 mm).

4 rows (content 80 holes / cm with diameter 0.14 mm).

Determination of cigarette filter characteristics:

Pressure drop in cigarette filter:

The pressure drop in cigarette filter was measured according to ISO 6565, 2011 by using QTM6 (Quality Testing Machine) (Cerulean Co., England), at Eastern Co. Lab., 6 October City, Egypt. Cigarette filter pieces were placed in the machine device and the pressure drop of cigarette filter was recorded in digit.

Ventilation of cigarettes:

Ventilation of cigarettes was measured according to ISO 9512, 2002 by using QTM5 (Cerulean Co., England), at Eastern Co. Lab., 6 October City, Egypt. Cigarettes were placed in the machine device and ventilation of cigarettes were recorded.

Diameter of cigarettes:

Diameter of cigarettes was measured according to ISO 2971, 2013 by using QTM3 (Cerulean Co., England), at Eastern Co. Lab., 6 October City, Egypt. Diameter in digit was recorded.

Length of cigarettes and cigarette filter measurement:

Length of cigarettes was measured by digital caliper (U. FA Co., Germany), at Eastern Co. Lab., 6 October City, Egypt.

Total weight of cigarettes:

Total weight of cigarettes was measured by using QTM8 (Cerulean Co., England), at Eastern Co. Lab., 6 October City, Egypt. Total weight of cigarettes in digit was recorded.

Determination of total particulate matters (TPM):

The total particulate matters were determined according to ISO 4387, 2008 by using smoking machine lx20 (Hauni Co., Germany) as shown in (fig.1.) at Eastern Co. Lab., 6 October City, Egypt.as follows:

The cigarettes were conditioned at 22°C and 60% humidity for at least 48 h before analysis. The smoking machine was run at the same condition of cigarettes. The cigarettes were placed in the smoke traps (5 cigarettes) of the smoking machine. The smoke traps were weighted_before and after each run to the nearest 0.1 mg. TPM was calculated as follows:

$$m\mathrm{TPM} = \frac{\mathrm{m1-m0}}{\mathrm{q}}$$

Where

$mTPM$= The mass of the total particulate matters for each channel, in milligram per cigarette.

$m0$ = The mass of the smoke trap before smoking, in milligrams.

$m1$ = The mass of the smoke trap after smoking, in milligrams.

q = The number of cigarettes smoked into the trap.

Fig.1. The smoking machine

Extraction of nicotine and tar from smoking trap(TPM)

Nicotine and tar were extracted from TPM according to ISO 4387, 2008 by using solvents Isopropanol 995 ml, heptadecane 0.2ml and ethanol 4.8ml per 1liter (Sigma Chemical Co., St., Louis, USA), at Eastern Co. Lab., 6 October City, Egypt. As follows:

The smoke traps were removed from the smoking machine. The folded filters of smoking machine were placed in an appropriately shaped dry flask (maximum 150 ml for 44 mm discs, maximum 250 ml for 92 mm discs). The inner surfaces of the smoking traps were wiped by specific filters then the solvents (Isopropanol 995 ml, heptadecane 0.2ml and ethanol 4.8ml per 1 1liter) were added to the mix in the flask and was shaked it gently on an electric shaker for at least 20 min.

Nicotine and tar determination:

Nicotine was determined according to ISO 10315, 2013 by using gas chromatographic pro GC+ (Thermo Co., United Kingdom), at Eastern Co. Lab., 6 October City, Egypt. As follows:

Aliquots (2 µl) from the mix was Injected into the gas chromatograph.

The ratio of the nicotine and water peak was calculated from standard peak.

Suitable operated conditions were as follows:

Column temperature was 170 °C (isothermal), injection temperature 250 °C, detector temperature 250 °C, carrier gas was helium at a flow rate of about 30 ml/min and injection volume 2 µl. The analysis time was about 6 min to 8 min. The packed column 7% PEG 20000 plus 3% poly phenyl ether was used.

DPM (on dry basis) was calculated from water calculated according to ISO 10362, 2011 by following equation:

$$mDPM = mTPM - mw$$

Where

$mDPM$ = The mass of DPM for each trap, in milligrams per cigarette.

$mTPM$ = The TPM content, in milligrams per cigarette.

mw = The water content in the TPM, in milligrams per cigarette.

The $NFDPM$ content $mNFDPM$ for each trap, expressed in milligrams per cigarette were given by the following equation**:**

$$mNFDPM = mDPM - mN$$

Where

$mNFDPM$ = The scientific acronym for tar. It stands for Nicotine Free Dry Particulate Matters each trap, in milligrams per cigarette.

$mDPM$ = The mass of DPM content, in milligrams per cigarette.

mN= The mass of nicotine content in the TPM, in milligrams per cigarette**.**

Nicotine retention efficiency was calculated as follows:

$$= \frac{Available\ nicotine - nicotine\ content}{Available\ nicotine} \times 100$$

Where

Available nicotine = the mass of nicotine in cigarette without filter, in milligrams per cigarette**.**

Nicotine content = the mass of nicotine in cigarette, in milligrams per cigarette**.**

tar retention efficiency was calculated as follows:

$$= \frac{Available\ tar - tar\ content}{Available\ tar} \times 100$$

Where

Available tar = the mass of tar in cigarette without filter, in milligrams per cigarette**.**

Tar content = the mass of tar in cigarette, in milligrams per cigarette**.**

Sensory evaluation of the smoking characteristics:

Smoking characteristics of the prepared cigarettes were carried out according to Kozlowski et al, 1996 and Elton et al, 2010. The sensory smoking characteristics of the samples A (Cleopatra Queen from Eastern Co., 6 October City, Egypt.), C (developed brand with 2 rows), D (developed brand with 4 rows) and the foreign samples i.e. Viceroy red (from BAT Co., Egypt) Marlboro red and LM red (from PMI Co., Egypt) were evaluated by 50 panelists (smokers) from the staff of Eastern Co., 6 October city, Egypt. All samples were evaluated for the pressure drop of cigarettes (25), vent of the cigarettes (15), vent of the cigarette filter (15), speed of burning the tobacco rod (15), change the color of the cigarette filter (20) and the stability of ash formed (10).

Statistical analysis

LSD (Least squares difference) test was used to compare the significant differences between means of treatment from table 3 to table 8 (Waller and Duncan, 1969).

RESULTS

Cigarette filter evaluation: Cigarette filters characteristics as affected by change in

components and conditions of processing were evaluated as presented in tables 1, 2, 3, 4 and 5:

Effect of cellulose acetate in cigarette filter

Quality characteristics of cigarette filter as affected by increasing weight of cellulose acetate from 200 to 210 mg cellulose acetate /cigarette were evaluated as presented in table (1). Results in (table 1) show an improvement in cigarette characteristics by increasing the cellulose acetate in cigarette filter from 200 mg/cigarette to 210 mg/cigarette. The cigarette characteristics i.e. efficiency for nicotine and tar retention and the pressure drop of cigarette were increased from 24.68% to 43.67% and from 36.05% to 47.68% and 130 mmWG to 142 mmWG, respectively. While ventilation of cigarette was decreased from 15.84% to 14.46%. Increasing cellulose acetate in the composition of the cigarette filter could increase tar and nicotine retention and consequently decrease amount of nicotine and tar taken by consumers. This could reduce the harmful effect of these two harmful components. However this effect increased the pressure drop in cigarette from 130 mmWG to 142 mmWG which could cause difficulty in smoking and consumer acceptance. In addition this also increase the amount of cellulose acetate consumed on an industry basis and consequently increased the cost. Practically it was found a high consumption of cellulose acetate at 210 mg/cigarette than that needed at 200 mg/cigarette (i.e. 10 kg consumed to one million of cigarette for using 210 mg/cigarette). This means increasing the cigarette filter cost (40$ per million cigarettes over the normal cost). Kozlowski et al, 1980 reported that the increase in weight of cellulose acetate in cigarette filter and ventilation of the cigarettes increased the efficiency of cigarette filter retention for nicotine and tar.

Effect of Tipping paper rows

Smoking cigarette characteristics as affected by using tipping paper rows at 1, 2 and 4 were evaluated as presented in table (2)

Results in (table 2) show that the smoking characteristics of cigarette were affected by the change in tipping paper rows from 1 to 2 and 4 (20, 40 and 80 holes/cm, respectively). At 200 mg cellulose acetate the smoking characteristics were improved by increasing the tipping paper rows from 1to 2 and 4. Nicotine and tar retention were increased from 35.58 to 36.51 and 39.42%, and! 49.69 to 51.68 and 54.65%, respectively. Ventilation was also increased from 14.96 to 27.47 and 32.99%, respectively. This could be as a result of increasing the number of holes from 20 to 40 and 80 holes/cm (1, 2 and 4 rows). Pressure drop of cigarette was decreased from 113 to 106 and 93 mmWG, at 1, 2 and 4 rows. The same parameters were also improved by increasing cellulose acetate from 200 to 210 mg / cigarette. At 210 mg cellulose acetate / cigarette. The nicotine and tar retention were increased from 44.71 to 55.77% and 58.65, and! 56.54 to 58.66 and 62.20%, respectively. Ventilation was also increased from 12.66 to 25.67 and 31.21%, respectively. Pressure drop of cigarette was decreased from 117 to 112 and 102 mmWG, respectively. This indicates that at 200 mg cellulose acetate and increasing tipping paper rows from 1 to 2 and 4, the ventilation and nicotine and tar retention were increased. At 210 mg cellulose acetate the retention of nicotine and tar had slightly increased. However such increase in cellulose acetate caused a decrease in ventilation of cigarette and an increase in the pressure drop of cigarette, since it couldn't be acceptable by the consumer.The increase in the number of rows increased the ventilation and improved the nicotine and tar retention and smoking cigarettes characteristics. The increase in nicotine and tar retention could eliminate the most of harmful effect of smoke. However, increasing ventilation increased the number of puffs and time of smoking and consequently decreased the consumer acceptance. Baker et al, 2001 reported that the cigarette filter characteristics depends on processing conditions such as degree of ventilation, number of vent holes, size of vent holes and number of rows.

Effect of ventilation on pressure drop

Smoking characteristics of cigarettes as affected by filter pressure drop (i.e. 58, 67 and 68 mmWG) and tipping paper 1, 2 and 4 rows were evaluated and presented in table (3). (Table 3) shows that the smoking characteristics of cigarette were affected by the change in pressure drop of cigarette filter. At 200 mg cellulose acetate / cigarette and 1 to 2 and 4 rows and at pressure drop of filter 67 mmWG the smoking characteristics were improved. Nicotine and tar retention were increased from 37.06 to 44.76, 46.15 and 52.44%, and! 54.09 to 56.14, 56.8 and 63.93%, respectively. Ventilation was decreased at 1 row from 15.31 to 14.72% which could be rejected by consumers. And Pressure drop of cigarette was increased from 105 to 123 mmWG at 1 row.

Table 1 smoking characteristics of cigarettes at 200 and 210 mg cellulose acetate /cigarette.

Brand *	Length of a cigarette (mm)	Length of the filter (mm)	Length of tobacco rod (mm)	Diameter Of Cigarette (mm)	Total weight of cigarette (mg)	Weight of tobacco only (mg)	Weight of filter and paper cigarette (mg)	Pressure drop of filter (mm WG)	Pressure drop of cigarette (mm WG)	Nicotine released in smoke (with filter) (mg)	Tar released in smoke(with filter) (mg)	Nicotine content in cigarette (with	Tar content in cigarette (without filter) (mg)	Rows (no.)	Ventilation of Cigarette (%)	Nicotine retention efficiency (%)	*Tar retention efficiency (%)*
A	80	20	60	7.8	958	750	200	62	130	1.19	14.66	1.58	22.92	1	15.84	24.68 b	36.05 b
B	80	20	60	7.8	968	750	210	68	142	0.89	12.29	1.58	22.92	1	14.46	43.67 a	47.68 a

Table 2 smoking characteristics of cigarettes at tipping paper 1, 2 and 4 rows.

Brand*	**Length of a cigarette (mm)**	**Length of the filter (mm)**	**Length of tobacco rod (mm)**	**Diameter of cigarette (mm)**	**Total weight of cigarette (mg)**	**Weight of tobacco only (mg)**	**Weight of filter and paper cigarette (mg)**	**Pressure drop of filter (mm WG)**	**Pressure drop of cigarette (mm WG)**	**Nicotine released in smoke (with filter) (mg)**	**Tar released in smoke (with filter) (mg)**	**Nicotine content in cigarette (without filter) (mg)**	**Tar content in cigarette (without filter) (mg)**	**Rows (no.)**	**Ventilation of cigarette (%)**	**Nicotine retention efficiency (%)**	**Tar retention efficiency (%)**
A	80	20	60	7.8	950	750	200	63	113	1.34	14.7	2.08	29.22	1	14.96 e	35.58 e	49.69 e
B	80	20	60	7.8	950	750	200	63	106	1.32	14.08	2.08	29.22	2	27.47 c	36.51 f	51. 68 f
C	80	20	60	7.8	950	750	200	63	93	1.26	13.25	2.08	29.22	4	32.99 a	39.42 d	54.65 d
D	80	20	60	7.8	960	750	210	71	117	1.15	12.7	2.08	29.22	1	12.66 f	44.71 c	56.54 c
E	80	20	60	7.8	960	750	210	71	112	0.92	12.08	2.08	29.22	2	25.67 d	55.77 b	58.66 b
F	80	20	60	7.8	960	750	210	71	102	0.86	11.05	2.08	29.22	4	31.21 b	58.65 a	62.20 a

*A = Cleopatra Queen (Control), B = Sample with 2 rows, C = Sample with 4 rows, D = Sample with 210 mg cellulose acetate and 1 row, E= Sample with 210 mg cellulose acetate and 2 rows, F= Sample with 210 mg cellulose acetate and 4 row

Means followed by a small letters in common in the same column are not significantly different at 0.05 level of probability.

But at 2 and 4 rows the ventilation was increased from 15.31 to 40.80 and 42.09%, pressure drop of cigarette was decreased from 105 to 103 and 83 mmWG.At 210 mg cellulose acetate / cigarette and 1 to 2 and 4 rows and at pressure drop of filter 68 mmWG the characteristics of filter had more improvement by using more weight from cellulose acetate and increased the pressure drop in filter. The nicotine and tar retention were increased from 49.66 to 55.24 and 60.84, and! 28.60 to 56.51 and 65.14, respectively. Ventilation of cigarette was also increased from 14.34 to 39.93 and 40.81. While the increasing in ventilation by increasing the rows caused a decrease in the pressure drop of cigarette from 128 to 112 and 93.

Increasing the pressure drop of cigarette filter increased the efficiency of nicotine and tar retention of cigarette filter thus reducing the harmful effect of consumers. On the other hand consumers reject the cigarette with high pressure drop because hard smoking. In this case an increase in the efficiency of nicotine and tar was found by increasing the ventilation of cigarette and using more weight of cellulose acetate.

At 200 mg cellulose acetate, the minimum accepted pressure drop of filter was 58 mmWG. At 210 mg cellulose acetate the pressure drop of filter was manually increased to 68 mmWG (It could increase the filter retention efficiency).

Evans et al, 1975 reported that the pressure drop of cigarette filter had a direct effect on the smoking characteristics.

Effect of filter paper CU (CORESTA Unit) on cigarette ventilation

Cigarette ventilation as affected by filter paper CU at 4000 and 8000 were evaluated as presented in table (4)

Results in (table 4) show that the smoking characteristics of cigarette were affected by the change in CU of filter paper from 4000 to 8000.

The smoking characteristics were improved by increasing CU of filter paper from 4000 to 8000 CU. At 200 cellulose acetate and at rows from 1 to 2 and 4, nicotine and tar retention were increased from 40.13 to 44.62, 54.61 and 56.2%, and! 46.65 to 49.16, 63.55 and 67.1%, respectively. Ventilation was also increased from 11.3 to 19.21, 52.13 and 54.3%. While pressure drop of cigarette was decreased from 115 to 103, 85 and 67 mmWG. In last case the characteristics of filter were improved by increased ventilation through the increase in CU of paper filter and rows of tipping paper.

At 210 cellulose acetate and at rows from 1 to 2 and 4, nicotine and tar retention were increased from 44.61 to 48.46, 59.23 and 62.31%, and! 48.87 to 51.54, 64.31 and 70.14%, respectively. Ventilation was also increased from 11.13 to 18.89, 49.23 and 53.46% while pressure drop of cigarette was decreased from 135 to 126, 103 and 83 mmWG. In this case the characteristics of filter were improved by increased weight of cellulose acetate and increased ventilation through increasing CU of paper filter and rows of tipping paper.

Results also showed that the sample H was the best in nicotine and tar retention i.e. 62.31% and 70.14%, respectively, but not acceptable by consumer because the increasing rate of ventilation (i.e. 53.46%). The increase in the number of rows and CU of filter paper increased the ventilation and improved the nicotine and tar retention and smoking cigarettes characteristics and reduced the harmful effect. However, some cigarettes (very high ventilation) are not acceptable because it caused more vent. Song et al., 2017 reported that increased ventilation of cigarette reduced the air coming from the burning area, causing incomplete combustion and increasing toxic compounds. Harris, 2011 reported that the ventilated cigarette filter could be a magical process for the cigarette industry.

Evaluation of some foreign produced cigarettes produced by BAT (British American Tobacco) and PMI (Philip Morris International) and locally produced

Smoking characteristics of some foreign cigarettes i.e. Viceroy red, Marlboro red and LM red compared with locally samples (A) and modified (C)were evaluated as presented in table (5) Results in (table 5) show that the modified C sample (at 200 mg, paper of filter 8000 CU and also tipping paper at 2 rows) had the best characteristics i.e. nicotine and tar retention and acceptable ventilation compared to locally product A. Modified F sample (at 200 mg, filter paper of 8000 CU and also tipping paper at 2 rows) had almost sampling characteristics as C sample. However sample F industrially had more cost than C sample. C Sample was selected as the best product. And also had almost the same characteristics i.e. tar retention compared to foreign samples. The higher value i.e. ventilation and nicotine retention, for foreign compared to modified could be as results of using more filter length (21 and 22 ml compared to 20) and tobacco rod (61 and 62 ml compared to 60).

Table 3 Smoking characteristics of cigarettes at different filter pressure drop (i.e. 58, 67 and 68 mmWG) and tipping paper 1, 2 and 4 rows.

Brand*	Length of a cigarette (mm)	Length of the filter (mm)	Length of tobacco rod (mm)	Diameter of cigarette (mm)	Total weight of cigarette (mg)	Weight of tobacco only (mg)	Weight of filter and paper cigarette (mg)	Pressure drop of filter (mmWG)	Pressure drop of cigarette (mmWG)	Nicotine released in smoke (with filter) (mg)	Tar released in smoke (with filter) (mg)	Nicotine content in cigarette (without filter) (mg)	Tar content in cigarette (without filter) (mg)	Rows (no.)	Ventilation of cigarette (%)	Nicotine retention efficiency (%)	Tar retention efficiency (%)
A	80	20	60	7.9	909	710	200	58	105	0.9	12.66	1.43	27.57	1	15.31 d	37.06 g	54.09 g
B	80	20	60	7.9	909	710	200	67	123	0.79	12.09	1.43	27.57	1	14.72 e	44.76 f	56.14 f
C	80	20	60	7.9	909	710	200	67	103	0.77	11.91	1.43	27.57	2	40.80 b	46.15 e	56.8 d
D	80	20	60	7.9	909	710	200	67	83	0.68	9.94	1.43	27.57	4	42.09 a	52.44 c	63.93 b
E	80	20	60	7.9	919	710	210	68	128	0.72	11.19	1.43	27.57	1	14.34 e	49.66 d	58.60 c
F	80	20	60	7.9	919	710	210	68	112	0.64	11.72	1.43	27.57	2	39.93 c	55.24 b	56.51 e
G	80	20	60	7.9	919	710	210	68	93	0.56	9.61	1.43	27.57	4	40.81 b	60.84 a	65.14 a

Table 4 smoking characteristics of cigarettes with filter paper of 4000 and 8000 CU (CORESTA Unit) and tipping paper at 1, 2 and 4 rows.

*Brand**	*Length of a cigarette (mm)*	*Length of the filter (mm)*	*Length of tobacco rod (mm)*	*Diameter of cigarette (mm)*	*Total weight of cigarette (mg)*	*Weight of tobacco only (mg)*	*Weight of filter and paper cigarette (mg)*	*Pressure drop of filter (mm WG)*	*Pressure drop of cigarette (mm WG)*	*Nicotine released in smoke (with filter) (mg)*	*Tar released in smoke(with filter) (mg)*	*Nicotine content in cigarette (without filter) (mg)*	*Tar content in cigarette (without filter) (mg)*	*Rows (no.)*	*Ventilation of cigarette (%)*	*Nicotine retention efficiency (%)*	*Tar retention efficiency (%)*	*CU of filter paper*
A	80	20	60	7.9	907	707	200	61	115	0.78	12.97	1.3	24.31	1	11.3 f	40.13 g	46.65 h	4000
B	80	20	60	7.9	907	707	200	61	103	0.72	12.36	1.3	24.31	1	19.21 e	44.62 f	49.16 f	8000
C	80	20	60	7.9	907	707	200	61	85	0.59	8.86	1.3	24.31	2	52.13 c	54.61 d	63.55 d	8000
D	80	20	60	7.9	907	707	200	61	67	0.57	7.99	1.3	24.31	4	54.3 a	56.2 c	67.1 b	8000
E	80	20	60	7.9	917	707	210	67	135	0.72	12.43	1.3	24.31	1	11.13 f	44.61 f	48.87 g	4000
F	80	20	60	7.9	917	707	210	67	126	0.67	11.78	1.3	24.31	1	18.89 e	48.46 e	51.54 e	8000
G	80	20	60	7.9	917	707	210	67	103	0.53	8.67	1.3	24.31	2	49.23 d	59.23 b	64.31 c	8000
H	80	20	60	7.9	917	707	210	67	83	0.49	7.26	1.3	24.31	4	53.46 b	62.31 a	70.14 a	8000

Table 5 smoking characteristics of locally samples and some foreign cigarette produced by BAT and PMI companies.

Brand*	Length of a cigarette (mm)	Length of the filter (mm)	Length of tobacco rod (mm)	Diameter of cigarette (mm)	Total weight of cigarette (mg)	Weight of tobacco only (mg)	Weight of filter and paper cigarette (mg)	Pressure drop of filter (mm WG)	Pressure drop of cigarette (mm WG)	Nicotine released in smoke (with filter) (mg)	Tar released in smoke(with filter) (mg)	Nicotine content in cigarette (without filter) (mg)	Tar content in cigarette (without filter) (mg)	Ventilation of cigarette (%)	Nicotine retention efficiency (%)	Tar retention efficiency (%)
A	80	20	60	7.9	907	707	200	61	115	0.78	12.97	1.3	24.31	11.3 c	40.13 b	46.65 d
C	80	20	60	7.9	907	707	200	61	85	0.59	8.86	1.3	24.31	52.13 a	54.61 a	63.55 c
Viceroy Red	83	22	61	7.9	933	725	208	58	90	1.27	13.8	1.45	23.4	22.67 d	12.41 e	40.84 e
Marlboro red	83	21	62	7.8	866	657	207	66	98	1.14	10.74	1.62	30.48	29.32 b	35.8 c	65.42 a
LM Red	83	21	62	7.8	962	659	203	64	123	1.09	11.50	1.7	33.25	27.07 c	29.41 d	64.75 b

Table 6 sensory smoking characteristics evaluation of sample A (control), C, D, Viceroy Red, LM Red and Marlboro red.							
Brand*	**Pressure drop of cigarettes**	**Vent of the cigarettes**	**Vent of the cigarette filter**	**Speed of burning the tobacco**	**Change the color of the cigarette filter**	**Stability of the mass of ash formed**	**Total acceptability (%)**
A	14 b	15 b	15	8 b	12 a	5 bc	69 a
C	17 a	15 b	15	9 ab	11 a	5 bc	72 a
D	5 c	13 a	15	3 c	6 b	5 c	47 b
Viceroy Red	17 a	15 b	15	9 ab	11 a	5 ab	72 a
Marlboro red	17 a	15 b	15	10 a	11 a	6 a	74 a
LM Red	16 ab	15 b	15	9 ab	11 a	6 a	72 a

*A = Control sample, C = Sample with 2 rows, D = Sample with 4 rows, *Viceroy Red= brand from BAT Company, Marlboro red and LM Red= brands from PMI Company.*

Sensory evaluation of the smoking characteristics

Sensory evaluation of the smoking characteristics for some foreign cigarettes i.e. Viceroy red, Marlboro red and LM red compared with locally sample (A), modified (C and D) were presented in table (6)

Results in (table 6) show that the modified sample had almost the same total acceptably compared to the foreign samples (72, 72, 74 and 72). The modified sample had also high total acceptance (72) compared to locally product cigarette (69).

Modification of sample C improved the sensory smoking characteristics i.e. Pressure drop, Change the color of the cigarette filter, Stability of the mass of ash formed and ventilation of cigarette.

The low acceptance of sample D because of high ventilation (54.3) that is not preferred by consumers.

CONCLUSION

Above study reviewed that the best sample was C in treatment No.4 (paper of filter 8000 CU and also tipping paper at 2 rows at 200 mg) since it caused increase for nicotine and tar retention (54.61%) and (63.55%), respectively, ventilation of cigarette (52.13%) and a decrease in the pressure drop of cigarette (85 mmWG) with comparing to the other treatments. The C sample cost was the same as in the control sample. The D sample (filter paper of 8000 CU and also tipping paper at 4 rows) better than C sample in retention efficiency but it was rejected in Sensory evaluated of smoking characteristics. The G and H samples (filter paper of 8000 CU and also tipping paper at 2 and 4 rows with 210 mg cellulose acetate) better than C and D samples in retention efficiency but it need more cost.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

S. Mohsen and A. Ammar contributed in the research idea and designed the experiments and reviewed the manuscript, A. Ateya processed the experiments also wrote the manuscript. All authors read and approved the final version.

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