



Sub-Group Cigars

Technical Report

**Summary
of 4 Collaborative Studies Results
2002 - 2004**

May 2005

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1. INTRODUCTION

In the 1990's, the objectives of the CORESTA Sub-Group Cigars were defined as follows:

- 1) To investigate the problems associated with the mechanical smoking of cigars;
- 2) To develop a method for the mechanical smoking of cigars that provides a credible and useful comparison of the smoke chemistry of cigars of all shapes and sizes;
- 3) To prepare and publish a practical method for sampling and mechanical smoking of cigars which meets the second term of reference.

In January 2002 the subgroup presented a first interim report on its activities carried out until that date. The subgroup concluded:

- 1) Smoking cigars of *all shapes and sizes*, based on one single set of parameters, does not provide a credible and useful comparison of their smoke chemistry;
- 2) The Sub-Group is of the opinion that the smoking regime currently used is suitable for the machine-smoking of cigars with a weight up to a maximum of 3 g¹. By this limitation the majority of the brands available on the market is covered (e.g. 81 % in the European market);
- 3) The Sub-Group Cigars proposes to the Scientific Commission to allow the Sub-Group to further investigate the machine-smoking of cigars beyond the weight limit of 3 g by an alternative smoking regime(s). The Sub-Group members are determined to complete the development of a method that meets the objectives as laid down by the Scientific Commission.

During its meeting in Atlanta on 18 January 2002, the Scientific Commission discussed the interim report, and requested the subgroup to publish a Technical Report on the work achieved up to January 2002, and to continue to work on a smoking method applicable to all cigars.

In April 2002 the subgroup finalised the requested Technical Report. The report contained the protocols and reports on 5 Collaborative Studies, the above mentioned interim report, and Draft 4 of four Recommended Methods. The draft Recommended Methods described the determination of nicotine, water, total and nicotine-free dry particulate matter (NFDPM), and the routine analytical smoking machine, all for cigars up to a weight of 3 grams. The Scientific Commission discussed the Technical Report during its meeting in Bayreuth, Germany, on 15 and 16 May 2002. During this meeting the Scientific Commission was informed about - and agreed to - the proposed new directions for completion of a smoking method for all cigars, by using different sets of smoking parameters, depending on the cigar volume.

¹ At the start of the 8th Collaborative Study it was agreed that this limit should be established at a diameter of 12 mm (see chapter IV).

2. 6TH COLLABORATIVE STUDY, MAY – OCTOBER 2002

From May until October 2002 12 laboratories carried out a 6th Collaborative Study in three groups. The objective of this study was to evaluate the interaction between puff volume, puff frequency, cigar volume and air flow through the burning cone. The three groups each smoked cigars with a different puff volume of 30, 40 or 50 ml respectively. Three different cigar models A, B and C were supplied to all participating laboratories. The laboratories had to cut these three different models on three different lengths: 140mm, 120mm and 100mm. All cigars were smoked at three different frequencies, which meant that each laboratory had to smoke: 3(frequencies) x 3 (cigar models) x 4 (original length + 140/120/100mm) = 36 tests. 1 test was the average of 4 cigars smoked (in contradiction with 8 cigars in the original protocol).

In addition, all participating laboratories also smoked the shortest products (100mm) with a puff volume of 20ml and a frequency of 20 and 40 seconds. This resulted in 3 (products) x 2 (frequencies) = 6 additional tests. Here 1 test was the average of 8 cigars smoked.

Table II.I Smoking regimes 6th Collaborative Study

Puff Volume (ml)	20	30	40	50
Lab. Groups	All	1	2	3
Frequency (s)	20 40	20 50 80	20 50 80	20 50 80
No. of tests	6	36	36	36

The results of the 6th Collaborative Study were first discussed on 29 November 2002. It was agreed, that further and deeper studies on the data collected were needed. On 6 March 2003 a second discussion of the results took place. At that moment it was concluded that the best way to move forward would be to study:

- 1) an increase of the puff volume in steps of 5ml (from 20ml to 50ml (= maximum puff volume of most smoking machines) in relation to an increase of the internal cigar volume in steps of 7ml (< 10ml, 10-17, 17-24, 24-31, 31-38, 38-45 and > 45ml), keeping the puff interval constant at 40 seconds;
- 2) an increase of the puff volume in steps of 5ml (from 20ml to 50ml) in relation to an increase of the internal cigar volume in steps of 5ml (< 10ml, 10-15, 15-20, 20-25, 25-30, 30-35 and > 35ml), keeping the puff interval constant at 40 seconds;
- 3) all A-type cigars (diameter 13,9mm) with a puff volume of 30ml, all B-type cigars (diameter 16,3mm) with a puff volume of 40ml and all C-type cigars (diameter 18,3mm) with a puff volume of 50ml.

3. 7TH COLLABORATIVE STUDY, APRIL - MAY 2003

From April until May 2003 14 laboratories carried out a 7th Collaborative Study, with the intention to study the relationship between the physical characteristics of the product (volume, diameter) and the puff volume. The test cigars A, B and C were cut at 3 equal lengths each, and were then smoked in three different ways:

- 1) an increase of the puff volume in steps of 5ml (from 25ml to 50ml) in relation to an increase of the internal volume in steps of 7ml, keeping the puff interval constant at 40 seconds;
- 2) an increase of the puff volume in steps of 5ml (from 25ml to 50ml) in relation to an increase of the internal volume in steps of 5ml, keeping the puff interval constant at 40 seconds;
- 3) all A-type cigars (diameter 13,9mm) with a puff volume of 30ml, all B-type cigars (diameter 16,3mm) with a puff volume of 40ml and all C-type cigars (diameter 18,3mm) with a puff volume of 50ml.

The foregoing lead to a total of 26 smoking runs of 4 cigars per run, for those laboratories that were able to participate up to a puff volume of 50ml. For some laboratories however 35ml or 40ml was the maximum puff volume.

Table III.I Smoking regimes 7th Collaborative Study

Cigar volume in steps of 7 ml	Cigar volume in steps of 5 ml	Cigar diameter (mm)	Puff volume (ml)
10 – 17 ml	10 – 15 ml		25
17 – 24 ml	15 – 20 ml	13,9	30
24 – 31 ml	20 – 25 ml		35
31 – 38 ml	25 – 30 ml	16,3	40
38 – 45 ml	30 – 35 ml		45
45 →	35 →	18,3	50

The smoking parameters were modulated depending on the cigar volume: increasing puff volume, in steps of 5 ml, every 7 ml increase of cigar volume (ranging from 10 ml to 45 ml) and also for every 5 ml increase of cigar volume. Besides that, smoking parameters were also modulated depending on the cigar diameter: increasing puff volume, in steps of 10 ml, starting at 30 ml.

The results of the 7th Collaborative Study were discussed on 2 July 2003. The NFDPM results obtained generally increased when the cigar weight or the cigar volume increased. A logarithmic regression as a function of the cigar volume and the cigar weight was calculated for the different possibilities of smoking parameters modulation and the results were the following:

NFDPM

Table III.II NFDPM logarithmic regression 7th Collaborative Study

Smoking regime groups	NFDPM as a function of	R ²
Cigar volume in steps of 7 ml	cigar volume	0,45
Cigar volume in steps of 5 ml	cigar volume	0,59
Cigar diameter	cigar volume	0,97
Cigar volume in steps of 7 ml	cigar weight	0,31
Cigar volume in steps of 5 ml	cigar weight	0,46
Cigar diameter	cigar weight	0,97

NICOTINE

Table III.III Nicotine logarithmic regression 7th Collaborative Study

Smoking regime groups	NFDPM as a function of	R ²
Cigar volume in steps of 7 ml	cigar volume	0,0343
Cigar volume in steps of 5 ml	cigar volume	0,0876
Cigar diameter	cigar volume	0,2512
Cigar volume in steps of 7 ml	cigar weight	2E-05
Cigar volume in steps of 5 ml	cigar weight	0,0102
Cigar diameter	cigar weight	0,1028

The low correlation in nicotine is due to the fact that the blends of the 3 products used for the study have different total alkaloids contents (1,20%, 1,27% and 0,83% for products A, B and C respectively). From the above mentioned results it also becomes clear that by far the best correlation was found for subdividing the cigars in steps of cigar diameter. It was therefore decided to restrict the future collaborative studies to only one variable smoking parameter: the puff volume as a function of cigar diameter.

The idea behind the puff volume modulation as a function of cigar diameter is to maintain the same air velocity² through the burning cone.

² Air velocity was previously written as linear airspeed.

4. 8TH COLLABORATIVE STUDY, DECEMBER 2003 – MARCH 2004

From December 2003 until March 2004 13 laboratories carried out an 8th Collaborative Study, with the aim to achieve a constant air velocity through the burning cone for cigar models with a diameter $\geq 12,1$ mm (approximately equivalent to a weight of 3 grams). This air velocity was equivalent to the one obtained at the end of the range of cigars $\leq 12,0$ mm diameter. To obtain such a constant air velocity, the puff volume was changed accordingly up to a maximum of 50 ml, which was the maximum available in the participating laboratories. The rest of the smoking parameters remained unchanged.

Seven commercial products plus the CM4 test piece (product code D) were smoked, each of the commercial products belonging to pre-established diameter ranges. Each range was smoked with a puff volume increase of 5 ml compared to the previous one, starting from 20 ml up to 50 ml:

Table IV.I Smoking regimes 8th Collaborative Study

Product code	Cigar diameter (mm)	Puff volume (ml)
D	8,0	20
K	11,1	20
L	12,7	25
A1	13,9	30
M	14,6	35
N	15,5	40
B1	16,3	45
C1	18,3	50

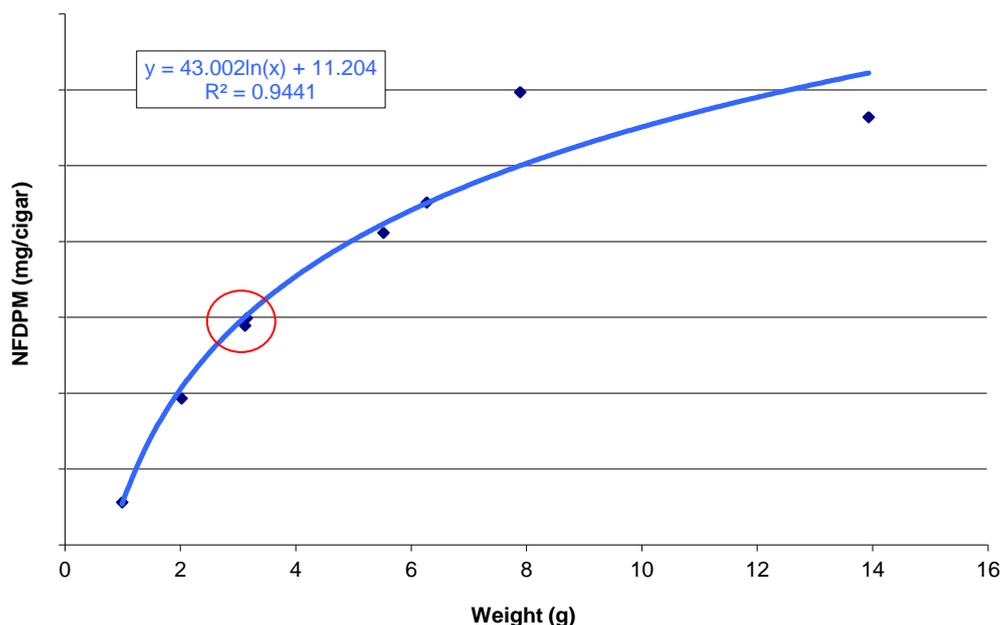
It was agreed to smoke 8 cigars in order to obtain 1 single result, 5 replicates and 1 cigar per filterpad. For the big cigar models, a laboratory had to spend 5 working days to obtain the 5 replicates. Forty working days were needed to accomplish the smoking of all test cigars.

The results of the 8th Collaborative Study were discussed on 5 May 2004. Among others it was concluded that:

- 1) Based upon a logarithmic relationship, the correlation between average NFDPM and cigar weight was above 0,90 for most laboratories;
- 2) Based upon a logarithmic relationship, the correlation between average nicotine and cigar weight was considerably lower for most laboratories. However, this result was to be expected as the tobacco nicotine content was different for the products tested;
- 3) Both in absolute as well as in relative terms, the repeatability "r" and reproducibility "R" were considerably higher for all products tested as compared to the standard cigarette smoking of the CM4.

The NFDPM results obtained generally increased with increasing cigar weight. A logarithmic regression as a function of the cigar weight was calculated, and is shown in the graph on the following page. Two out of the eight cigars smoked had similar weight but different diameter. They are inside the ellipse in the graph. Despite the fact that they were smoked under different smoking parameters, they gave very similar NFDPM results, suggesting that the puff volume modulation (resulting in the same air velocity) leads in the right direction.

NFDPM LOGARITHMIC REGRESSION



In order to be able to compare possible differences in the “r” (repeatability) and “R” (reproducibility) between the cigar method and the cigarette method, the CM4 test piece was smoked during this study as well. The “r” and “R” results obtained were clearly higher than in the cigarette method:

Table IV.II Comparison CM4 r and R 8th Collaborative Study

	r relative % cigarette method	r relative % cigar method	R relative % cigarette method	R relative % cigar method
Nicotine	6	13	10	28
NFDPM	5	16	11	42

For NFDPM the relative repeatability within laboratories (“r”) was 3 times higher than for the cigarette method. The reproducibility inter laboratories (“R”) was almost 4 times higher than for the cigarette method. Of course this is partly caused by the fact, that we consider one result to be the average of 8 cigars smoked, whereas the cigarette method uses 20 cigarettes for one result.

5. 9TH COLLABORATIVE STUDY, AUGUST – OCTOBER 2004

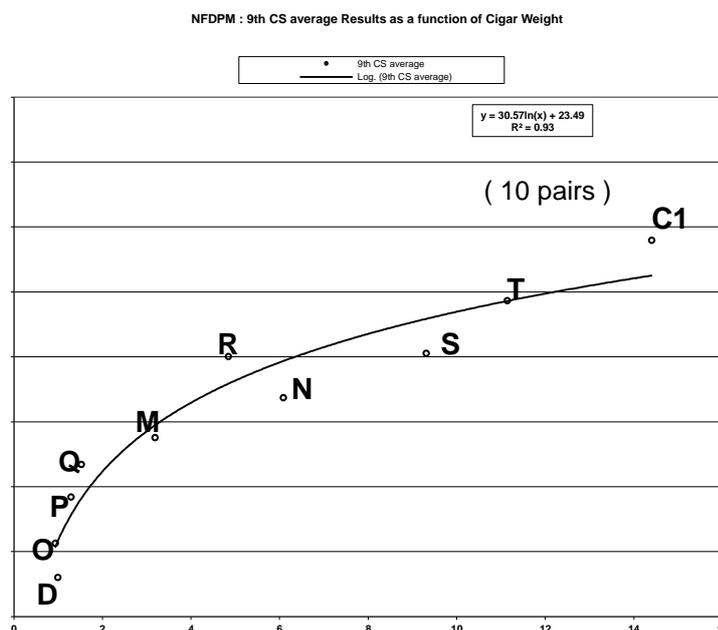
From August until October 2004 15 laboratories carried out a 9th Collaborative Study. Nine different cigars plus the CM4 test piece were smoked, covering a range of cigar diameters from 8 mm to 18,30 mm.

Table V.I Smoking regimes 9th Collaborative Study

Product code	Weight (g)	Length (mm)	Cigar diameter (mm)	Puff volume (ml)
D	1,00	84,0	8,0	20
O	0,95	75,0	8,5	20
P	1,36	87,7	9,0	20
Q	1,60	99,0	9,1	20
M	3,25	95,0	14,6	30
R	5,10	129,5	13,7	26
N	6,60	127,0	15,5	33
S	9,60	164,0	17,0	40
T	11,27	162,0	17,5	43
C1	14,28	174,0	18,3	47

Cigars with a diameter $\leq 12,0$ mm were smoked with a puff volume of 20 ml. For cigars with a diameter between 12,1 and 19 mm the puff volume was continuously modulated in order to obtain a constant air velocity of 11,8 cm/s. Finally, for cigars with a diameter of more than 19 mm the puff volume was limited to 50 ml because of technical reasons. The purpose of the study was to determine the repeatability and reproducibility for the yields obtained from these products when smoked according to these rules.

The NFDPM results obtained generally increased with increasing cigar weight. A logarithmic regression as a function of the cigar weight was calculated, and is shown in the following graph.



The results of the 9th Collaborative Study were discussed on 14 and 15 December 2004. Among others it was concluded that, in absolute as well as in relative terms, the repeatability “r” and reproducibility “R” were considerably higher for all products tested as compared to the standard cigarette smoking of the CM4.

Table V.II Comparison CM4 r and R 9th Collaborative Study

	r relative % cigarette method	r relative % cigar method	R relative % cigarette method	R relative % cigar method
Nicotine	6	7	10	23
NFDPM	5	9	11	28

The relative repeatability (r%) and reproducibility (R%) for NFDPM and nicotine for the cigars tested increased with the size of the cigar:

- For NFDPM the relative “r” increased from 10 to 28% and relative “R” from 28 to 89%;
- For nicotine the relative “r” increased from 10 to 30% and relative “R” from 30 to 123%.

These findings confirm that the product variability, inherent to cigar production, is reflected in the high variability of the smoke yields when cigars are machine-smoked. Due to the wide range of products, cigars cannot be smoked in a fully automated manner. Next to the effect of the number of cigars (average of 8 cigars compared to 20 for cigarettes), the increase in the relative repeatability and reproducibility demonstrate the inherent characteristics of the product itself and the production process.

6. RECOMMENDED METHODS

During the consecutive Collaborative Studies draft methods for the measurement of Nicotine, Water and NFDPM (Nicotine Free Dry Particulate Matter) in the mainstream smoke of cigars were reviewed, and the description of a Routine Analytical Cigar-smoking Machine was completed.

To date, the following drafts are available:

- Method N° WW: Determination of nicotine in mainstream smoke of cigars by GC,
- Method N° XX: Determination of water in mainstream smoke of cigars by GC,
- Method N° YY: Routine analytical smoking machine for cigars ,
- Method N° ZZ: Determination of total and nicotine-free dry particulate matter using a routine analytical cigar-smoking machine.

7. DISCUSSION ON VARIABILITY

The 8th and 9th Collaborative Studies showed a wide spread of smoke yields, reflected in high repeatability (r) and reproducibility (R) figures, both in absolute as well as in relative terms. As it was stated before, this is partly caused by the fact, that we consider one result to be the average of 8 cigars smoked, whereas the cigarette method uses 20 cigarettes for one result. Due to the wide range of products, cigars cannot be smoked in a fully automated manner.

More importantly however, the high cigar variability is mainly caused by reasons related to the cigar production system and to the inherent characteristics of the product itself:

Production related reasons

Very great dispersion of the weight, density, pressure drop, length and circumference of the products, due to:

- Different - relatively low technology - machine systems;
- The production often takes place in small batches, especially in the higher price-classes;
- Some cigars are handmade;
- Difficulties in controlling the porosity and gluing of the natural binder and -wrapper giving rise to additional variability.

Product related reasons

- Great range of the tobaccos used for filler, wrapper and binder:
- Tobacco is a natural product. The thickness, texture, porosity and combustibility of the leaves vary substantially;
- For binder and wrapper sometimes there are only a few bales available because of the sorting according to harvesting by grade, colour and length and the next batch may differ significantly;
- The filler tobaccos for most cigars are threshed. For long filler cigars the filler tobaccos are not threshed at all. The consequence is a different size of the particles and therefore non-homogeneity of the filler within a cigar. This influences the pressure drop and the smoking characteristics of the cigar;
- The spirally rolled wrapper may allow air inflow;
- Headed cigars present a special problem, as the operator must cut them manually.

Expression of results

According to its second objective, the Sub-Group is required to develop a method for the mechanical smoking of cigars that provides a credible and useful comparison of the smoke chemistry of cigars of all shapes and sizes. Cigar manufacturing has a very high degree of variability. As the 9th Collaborative Study showed, depending on the cigar type, the relative "R" for NFDPM varied between 28% and 89% and for nicotine between 22% and 123%. The expression of tar and nicotine yields in cigar smoke as single numerical values would result in tar and nicotine yields being inconsistent between one batch and the next, and even within the same batch. It is

recommended to express cigar smoke yields as a lower and an upper value (i.e. mean plus and minus 2 times standard deviation).

Product code	R relative (%) NFDPM	Lowest value NFDPM	Highest value NFDPM	R relative (%) Nicotine	Lowest value Nicotine	Highest value Nicotine
O	28	18	27	32	1,0	1,5
P	26	30	44	33	1,9	3,1
Q	28	38	56	22	2,4	3,3
M	31	43	67	49	2,0	4,1
R	35	59	99	45	4,4	8,6
N	43	46	87	45	2,9	5,7
S	62	44	112	73	1,8	5,7
T	89	32	145	123	1,4	21,1
C1	65	57	155	81	2,1	7,8

This approach will require regular Collaborative Studies, as to build a database on repeatability- and reproducibility-data for products as found on the market.

Cigar weight ranges from less than 1 gram to more than 15 grams per unit. For that reason, the Sub-Group is of the opinion that the results should not only be expressed in mg/cigar, but also in mg/gram (being the result of dividing the total NFDPM by the total cigar weight of the sample). Doing so, more possibilities of comparison between products of different weights are established.

8. CONCLUSIONS AND FUTURE WORK

As was stated before, the objectives of the CORESTA Sub-Group Cigars were defined as follows:

- 1) To investigate the problems associated with the mechanical smoking of cigars;
- 2) To develop a method for the mechanical smoking of cigars that provides a credible and useful comparison of the smoke chemistry of cigars of all shapes and sizes;
- 3) To prepare and publish a practical method for sampling and mechanical smoking of cigars which meets the second term of reference.

The Sub-Group Cigars has developed a method that does provide a credible and useful comparison of the smoke chemistry of cigars of all shapes and sizes, which takes into consideration the practical, time consuming work of cigar smoking in laboratories. Furthermore a practical method for sampling (CORESTA Recommend Method No 47) was developed, as well as cigar holders for products from 6,5 up to 22,5 mm diameter.

This method for the machine smoking of cigars is a technical convention, only to be used for comparison between different cigar brands.

Ideally one should adapt the puff volume to the cigar diameter in a continuous manner. Only for reasons of simplicity it was decided to test whether the "constant air velocity" principle holds by dividing the test cigars in several diameter groups, and by increasing the puff volume in steps of 5ml. The principle proved to be correct, so the final draft method contains a simple formula calculating the puff volume as a function of the cigar diameter.

Future work still has to be done on:

- a more accurate measurement of the cigar diameter, as this measurement is a crucial factor for the determination of the puff volume. Standardisation of this measurement is required, given the spread of diameter results as reported by the different laboratories.
- periodical collaborative studies to improve r and R;
- the determination of the change in variability with increased cigar size;
- the establishment of tolerances for the smoke yields;
- carbon monoxide.