COMPARATIVE LEVELS OF CARBONYL DELIVERY BETWEEN MASS-MARKET CIGARS AND CIGARETTES

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Introduction

The recent 2016 deeming of cigars by the US Food and Drug Administration (FDA) has led to an increased interest in cigar science, including ways to accurately measure the harmful and potentially harmful constituents (HPHCs) found within mainstream cigar smoke. Even so, a survey of the literature found only a handful of studies which address carbonyl delivery with regards to cigars. These studies were limited in scope either by the number of products analyzed or analytes reported, and warranted further investigation.

At present, there are a limited number of standardized methods available for the evaluation of HPHCs in mainstream cigar smoke, except for nicotine and carbon monoxide. This study sought to investigate carbonyl delivery in commercially available cigars and cigarillos and compare them to levels found in cigarettes. First the standard cigarette method, CORESTA recommended method 74 (CRM-74), was optimized for cigar smoking, including evaluation of the trapping efficiency and the stability of the carbonyl-hydrazone adducts, due to the increased smoke time required for cigar collection. The optimized trapping solution was then applied in a survey of the carbonyl delivery in commercially available cigars and cigarillos for comparison to published cigarette data.

Trapping Solution Optimization

Optimization of the DNPH trapping solution was carried out to accommodate for extended smoke times required for cigar analysis. In addition to the trapping solution described in CRM-74, two additional trapping solutions were investigated, one consisting of 100% acetonitrile, and the other consisting of 75% acetonitrile and 25% water. Samples were collected at 0°C, with aliquots taken for analysis. Unquenched samples were analyzed while maintaining sample chamber at 4°C. The trapping solution consisting of 75% acetonitrile and 25% water displayed the best stability for all analytes of interest, with up to three hours with < 10% decrease in % relative response.

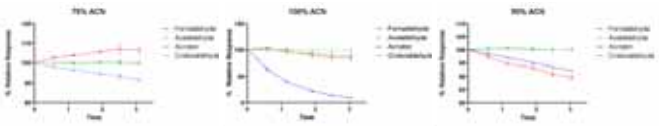

Figure 1. Effect of trapping solution acetonitrile composition on DNPH-hydrazone adduct stability

Breakthrough Analysis

Using the trapping solution consisting of 75% acetonitrile and 25% water, breakthrough analysis was performed through the addition of an extra impinger attached in series to the two impingers used during routine smoke collection. A machine-made cigar was smoked in triplicate and breakthrough was measured as a percent of the total carbonyl collection observed in the third impinger. It was found that >94% of the total carbonyl output was trapped in the first two impingers for formaldehyde, acetaldehyde, acrolein, and crotonaldehyde.

Table 1. Summary results of breakthrough analysis

	Formaldehyde (% Breakthrough)	Acetaldehyde (% Breakthrough)	Acrolein (% Breakthrough)	Crotonaldehyde (% Breakthrough)
Rep 1	4.68	ND	ND	ND
Rep 2	2.78	ND	ND	0.17
Rep 3	5.55	ND	ND	ND

Physicals Comparison

The physical properties of twelve brands of cigars and cigarillos were compared on the basis of weight (including tips where applicable), length, and diameter. Pressure drop analysis was also carried out. A one-way ANOVA analysis was performed comparing all the brands based on these physical properties, in which results indicate that each brand was statistically different ($P<0.05$). Further analysis treated all replicates for each of the twelve brands of cigars as a global (60-point), inter-brand sample set. Here, the %RSD for length, weight, and diameter were all less than 15%, suggesting that although statistically, each brand is different, practically, there is little difference between brands.

Results per Cigar Type

Twelve brands of cigars/cigarillos were smoked under the CRM-64 regime and evaluated for their average delivery of formaldehyde, acetaldehyde, acrolein, and crotonaldehyde. Although there was considerable variation, potentially reflecting differences in the cigar/cigarillo construction and tobacco composition, the observed carbonyl levels could be distinguished on the basis of cigar type. Carbonyl output was greatest for the tipped cigars and lowest for products classified simply as cigars. Cigarillos displayed carbonyl levels intermediate to the other two types. While it is possible that the observed differences may derive from the tobacco blends used, the data suggests that cigar type may have an influence on the carbonyl delivery.

Table 2. Summary of average carbonyl output based on cigar type

Cigar Type	Formaldehyde (µg/cig)	Acetaldehyde (µg/cig)	Acrolein (µg/cig)	Crotonaldehyde (µg/cig)
	Mean ± Stdev	Mean ± Stdev	Mean ± Stdev	Mean ± Stdev
Cigar	6.8 ± 2.5	1741 ± 340.8	22.3 ± 1.8	23.9 ± 0.9
Cigarillo	15.6 ± 2.3	2006 ± 301.9	43.8 ± 4.7	36.8 ± 3.5
Tipped Cigar	33.9 ± 6.3	2520 ± 187	81.3 ± 10.7	60.1 ± 6.3

Cigar vs Cigarette Delivery of Carbonyls per Unit

The carbonyl delivery of the twelve tested cigars was compared to both University of Kentucky 3R4F reference cigarettes and marketed cigarettes (data published by Counts et. al (2005)). Cigars were smoked according to CRM-64 and cigarettes according to both the ISO 3308 and ISO 20778 regimes.

ISO 3308

When comparing to marketed cigarettes smoked under ISO 3308 regime, it was found that average acetaldehyde (2133 ± 470 vs. 365 ± 176.5 µg/cig), acrolein (52.7 ± 23.7 vs. 33.4 ± 17.0 µg/cig), and crotonaldehyde (42.4 ± 14.7 vs. 14.7 ± 6.8 µg/cig) delivery was greater in the 12 cigar brands tested in this study than that of the examined cigarettes. It was observed that formaldehyde delivery was statistically the same in both cigars/cigarillos and cigarettes (20.2 ± 11.7 vs. 22.1 ± 13.5 µg/cig respectively; $P<0.05$). Similar trends were observed with 3R4F reference cigarettes.

ISO 20778

When comparing to marketed cigarettes smoked under ISO 20778 regime, it was found that average formaldehyde (20.2 ± 11.7 vs. 74.6 ± 24.0 µg/cig), acrolein (52.7 ± 23.7 vs. 120.5 ± 14.9 µg/cig), and crotonaldehyde (42.4 ± 14.7 vs. 51.5 ± 8.7 µg/cig) delivery was greater in cigarettes than in the 12 cigar brands tested. This was not unexpected as vent blocking and puff volume play a role in carbonyl delivery. Conversely, the average delivery of acetaldehyde was greater in cigars than in marketed cigarettes (2133 ± 470 vs. 1234 ± 147 µg/cig), which is not surprising as acetaldehyde is one of the primary constituents of mainstream smoke and cigars contain far more tobacco than cigarettes (Piadé et al., 2013). Similar trends were also observed with regards to 3R4F reference cigarettes.

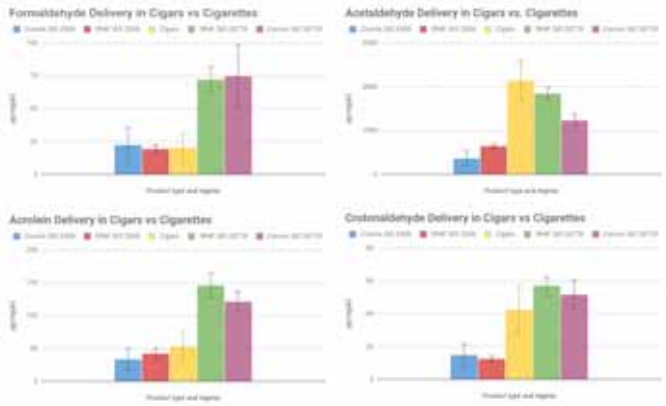

Figure 2. Comparison of carbonyl delivery between cigars and cigarettes on a per unit basis

Cigar vs Cigarette Delivery of Carbonyls Per Puff

Although the use of cigarettes per day is greater than that of cigars (Corey et al. (2017)) on a per-user basis, the size difference between the two product types can be considerable. In comparison to the 3R4F and marketed cigarettes used in the published studies, there is, on average, 3.3 – 4.5 times the amount of tobacco in cigars and therefore more to burn, potentially delivering greater carbonyl levels. Due to the increased size, the number of puffs required to smoke cigars and cigarillos will be larger than that needed to smoke cigarettes.

When comparing carbonyl delivery on a per puff basis, cigarettes smoked under either the ISO 3308 or ISO 20778 regimes produce each carbonyl (formaldehyde, acetaldehyde, acrolein, and crotonaldehyde) at higher levels than in cigars, except for acetaldehyde in marketed cigarettes smoked under ISO 3308 conditions. Under ISO 3308, the global study mean delivery reported for cigarettes by Counts et al. was 38.0 ± 16.6 µg/puff compared with 53.2 ± 12.0 µg/puff from the tested cigars. The same trends were also observed when comparing carbonyl delivery from cigars to that of 3R4F reference cigarettes.

It is important to keep in mind that the conditions under which the samples are smoked have a direct impact on carbonyl output. Variables such as puff volume, vent blocking, filter composition, and burn temperature all influence the delivery of carbonyls (Wagner et al., 2005). The puff volume for both ISO 3308 and ISO 20778 is greater than that used for cigars less than 12 mm in diameter following CRM-64, therefore, it is not especially surprising that on a per puff basis, the levels of carbonyls seen in cigarettes is greater than that observed in the cigars and cigarillos used for this study.

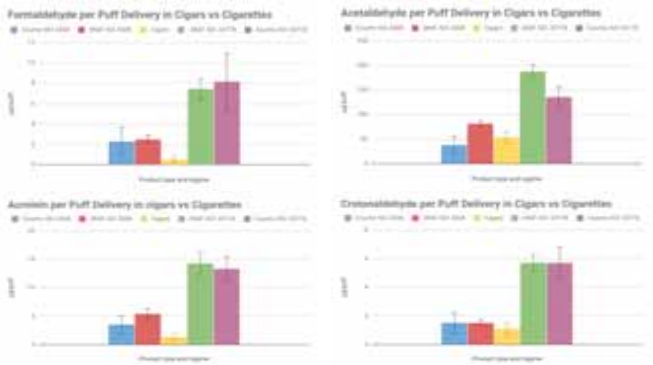

Figure 3. Comparison of carbonyl delivery between cigars and cigarettes on a per puff basis

Conclusion

The aim of this work was to expand the current understanding of carbonyl emissions in mainstream cigar smoke. The carbonyl delivery from cigars smoked under the CORESTA regime were either similar to (formaldehyde) or greater than (acetaldehyde, acrolein, crotonaldehyde) delivery measured from cigarettes under ISO 3308 smoking conditions on a per unit basis. Cigarettes smoked under the intense ISO 20778 smoking regime delivered higher levels of carbonyls than cigars smoked under the CORESTA regime, except for acetaldehyde which was higher in cigars on a per unit basis. Further work is suggested to expand the list of products analyzed to include a wider range of marketed products in both cigar size and type.

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