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Original investigation

Little Cigars, Filtered Cigars, and their Carbonyl Delivery Relative to Cigarettes

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Abstract

Introduction: Little cigars and filtered cigars are currently growing in popularity due to their low cost and wide variety of flavors while retaining an appearance similar to cigarettes. Given the health consequences associated with cigarette use, it is important to understand the potential harm associated with these similar products. This includes the potential harm associated with carbonyls (eg, acetaldehyde, acrolein, formaldehyde, etc.), an important class of toxicants and carcinogens in tobacco smoke. Our objective was to determine the carbonyl levels in mainstream smoke from little and filtered cigars compared to cigarettes.

Methods: We examined two brands each of little cigars and filtered cigars, as well as two research cigarettes for carbonyl delivery using the International Organization of Standards (ISO) and the Health Canada Intense (HCI) machine-smoking protocols.

Results: On a per puff basis, the levels of five of the seven carbonyls were higher from little cigars than filtered cigars and cigarettes (ISO: 56–116%; HCI: 39–85%; $p < .05$). On a per unit basis, most carbonyl levels were higher from both cigar types than cigarettes using the ISO method (ISO: 51–313%; $p < .05$) whereas only filtered cigars were higher using the HCI method (HCI: 53–99%; $p < .05$).

Conclusion: These findings suggest that cigar smokers can be exposed to higher levels of carbonyls per cigar than cigarette smokers per cigarette.

Implications: These data will increase our understanding of the relative harm from carbonyl exposure from little and filtered cigars both for cigar-only smokers and the cumulative harm among the growing population of cigarette–cigar multi-product smokers.

Introduction

Little cigars are small cigars with cellulose acetate filters that are similar in size, weight, and appearance to cigarettes. Since 2000, little cigars have been rising in popularity with their usage increasing from 2 billion units sold in 2000 to near 6 billion sold in 2008 whereas cigarette usage decreased during this time.[1,2] This popularity has been attributed to their similarity to cigarettes, lower cost compared to cigarettes, and variety of flavors.[3] To further stress their similarity, one study found 42% of smokers misclassified little cigars as cigarettes.[4] To combat the rise in little cigars sales, an increase in federal excise tax was added to little cigars in 2009 to set the tax equal to cigarettes.[5] Yet, to avoid this tax, tobacco companies changed their products to classify as large cigars by increasing the weight, which was done by adding sepiolite, a clay material also known as meerschaum, to the filter, elongating the products from 100 mm to 120 mm, and/or packing more tobacco to the cigar rod.[6] These new products are branded as filtered cigars (also known as filtered large cigars) as they still maintain a filter and, despite the added weight and length, have an appearance similar to cigarettes. Filtered cigars maintain a price lower than both cigarettes and little cigars. For example, in Dauphin County, PA, filtered cigars are $2 for a pack of 20 compared to $5 for a pack of 20 little cigars or cigarettes. Because of this price difference, filtered cigar sales have increased (exact numbers unknown as sales of these products are grouped with other large cigars, but large cigar sales rose from 6 billion units sold in 2008 to 13 billion in 2011)[1,2] with most smokers attributing their use of the product to price.[7] In addition, one study found that filtered cigars were currently being used by 2% of adults (0.4% daily users) whereas cigarettes are used by 18% (16% daily users) in 2013–2014;[8] however, with how often these products are mistaken for cigarettes (42% for little cigars and 34% for filtered cigars in one study),[4] it is highly probable that the usage of these products was actually higher.

Increased usage of filtered cigars and little cigars, the US Food and Drug Administration's (FDA) new deeming rule that regulates all cigar products,[9] and the recent warning letters sent to four companies that produce these products,[10] all suggest that understanding the potential harm and toxicant exposure of these types of cigars is an important area of concern. Currently, compared to cigarettes, little is known about the levels of toxic substances in mainstream smoke from these products. Carbonyls are one important class of toxicants found in tobacco smoke which has not been thoroughly investigated in little and filtered cigars. Seven carbonyls are listed on the FDA published list of 93 harmful and potentially harmful constituents (HPHC) in tobacco smoke: acetaldehyde, acrolein, acetone, formaldehyde, propionaldehyde, crotonaldehyde, and methyl ethyl ketone (MEK).[11] While carbonyls are abundant in cigarette smoke,[12–18] to date, there are few reports on their levels in little cigars and most focus on products which are no longer current or popular.[19,20] In one recent study, acrolein delivery in sheet-wrapped cigars was similar yet more variable than in cigarettes; however, no distinction was made between little cigars and filtered cigars.[21] To our knowledge there are no studies examining carbonyls in newer filtered cigars in comparison to either little cigars or cigarettes.

This is further complicated by the lack of data on smoking behaviors displayed by little and filtered cigar smokers. There is only one previous study by Pickworth et al. that examines puff topography for dual users of little cigars and cigarettes.[7] The study showed that the average puff topography of dual users using little cigars are similar to those when using cigarettes, albeit with a lower puff volume towards the end of the smoking session and slightly fewer puffs overall.[7] However, this study examined little cigar topography and not filtered cigars, assuming both products would be similar which might not be true as filtered cigars can have additional material in the filter that could potentially affect smoking topography. Thus, it is important to capture the range that is possible as established by cigarettes as the smoking topographies used for these products are still unclear.

Overall, our objective was to determine the carbonyl content in mainstream smoke from different brands of little cigars and filtered cigars when smoked under two controlled and standardized methods (International Organization of Standards, ISO, and Health Canadian Intense, HCI) and compare these results to levels observed both to each other and to those in conventional cigarettes, gaining a better understanding of the relative harm of these products. As these two topographies cover the vast majority of cigarette smoking topographies (~86%),[22,23] these methods provide a reasonable starting point for analyzing the carbonyl output from cigars across different topographies to better estimate if there are differences in potential harm to both single and dual users of these cigars.

Methods

Materials

Acetonitrile (ACN) and concentrated hydrochloric acid (12N HCl) were purchased from Fisher Scientific (Pittsburgh, PA) and used as supplied. Diglyme and dinitrophenylhydrazones of formaldehyde, acetaldehyde, crotonaldehyde, propionaldehyde, and MEK were purchased from Sigma-Aldrich (St. Louis, MO) and used as supplied. 2,4-Dinitrophenylhydrazine (DNPH) was purchased from BOC Sciences (Shirley, NY) and was recrystallized in acetaldehyde before use to remove water.[24]

Cigars and Cigarettes

The two little cigar brands (Winchester and Captain Black Sweets) and two filtered cigar brands (Cheyenne Full Flavor 100s and Criss Cross Full Flavor) were purchased locally by the researchers (Dauphin and Lebanon counties, PA). These brands were chosen as they are classified as little cigars and filtered cigars almost everywhere, whereas other brands might differ based on state statutes (ie, Santa Fe, Swisher Sweets, etc.). This is important as Pennsylvania law defines the cut-off of little and filtered cigars differently (4 lbs per 1000)[25] than federal law (3 lbs per 1000).[5] The 3R4F and 1R6F research cigarettes were obtained and shipped from the University of Kentucky (Lexington, KY) without refrigeration. These research cigarettes were used as a reference for cigarettes on the US market as previous studies have shown that the carbonyl levels delivered by these research cigarettes are comparable to the levels delivered from commercial cigarettes.[26,27] After purchase (cigars) and shipment (cigarettes), the cigars and cigarettes were stored at −80°C in airtight plastic bags. To condition the products properly, at least 24 h before use, the products were placed in a constant humidity chamber (60% relative humidity, 22 ± 1°C) to ensure similar moisture content across products.[28]

Mainstream Smoke Generation

Mainstream smoke was generated by a single-port smoking machine (Human Puff Profile Cigarette Smoking Machine (CSM-HPP), CH Technologies, NJ). One product was smoked at a time under the International Organization of Standardization (ISO; 35 mL puff volume, 2 s puff duration, 60 s interpuff interval)[29] and Health Canada Intense (HCI; 55 mL puff volume, 2 s puff duration, 30 s interpuff interval, ventilation blocked)[30] methods. Per puff yields were determined by dividing the average cigar/cigarette carbonyl yields by the number of puffs to smoke an entire cigar/cigarette and are not measured for each puff directly.

Derivatization of Carbonyls

DNPH solution was made as described previously[24,27,31] by dissolving 0.5 g recrystallized DNPH in 25 mL diglyme, 180 µL 12N HCl, and 75 mL ACN. Similar to previous work,[31] mainstream smoke generated from one cigarette/cigar using the CSM-HPP was pumped through Tygon tubing by the smoking machine pump to an impinger containing 10 mL of DNPH solution. The solution was then transferred into a scintillation vial, 500 uL of pyridine was added to ensure acrolein did not degrade with time, and stored at 4°C until HPLC-UV analysis. We performed two replicates of cigarettes and three replicates of cigars, meaning n = 4–6 for each product category. Cigarettes were only replicated twice each as the values and standard deviations were similar to those previously published.[27,31,32] Although samples were found to be stable for a minimum of 2 weeks under these conditions by testing the same samples over time, all HPLC-UV analyses were performed within 3 days of collection to permit ample time for reanalysis if necessary.

HPLC-UV Analysis

High performance liquid chromatography with ultraviolet detection (HPLC-UV) analyses were performed using a binary system consisting of two Waters (Milford, MA) 510 pumps, a Shimadzu (Kyoto, Japan) SPD-10A VP UV-Vis Detector, and a Hitachi (Tokyo, Japan) D-2500 Integrator. The method used was based on the CORESTA method, but has been optimized for use with two pumps instead of three.[32] This method was described previously[31] with a recovery for all carbonyls of >98% and a precision of ~12%. Briefly, the carbonyls were separated by a C18 column (Bondclone, 10 µm × 300 mm × 3.9 mm; Phenomenex, Torrance, CA) using 30% acetonitrile, 10% tetrahydrofuran, and 1% isopropanol (A) and 65% acetonitrile, 1% tetrahydrofuran, and 1% isopropanol (B) mobile phases. The elution gradient was: 0 min, 100% A; 8 min, 70% A; 16 min, 60% A; 20 min, 54% A; 22 min, 40% A; 25 min, 100% A; and 31 min 100% A. The flow rate was 1.5 mL/min, and the detection wavelength was 365 nm. All sample injections were 20 µL and injected with a Hewlett Packard (Palo Alto, CA) Series 1050 autosampler. All measurements were carried out at room temperature (22 ± 1°C).

Smoldering Analysis

To test the differences in smoldering rate, products were placed in the single-port smoking machine and lit using the ISO method. After the lighting puff, the distance from ashes to filter overwrap was measured to ensure that the amount lost to the first puff was not counted as part of the smoldering. Then, the ISO method was stopped, and the product was left alone for 3 minutes before measuring the product again. This was repeated in triplicate for each brand tested (n = 6 for each product type).

Physical Parameter Analyses

Ventilation was measured as previously described.[33] Lengths were measured using a Vernier caliper. Weights were determined using an analytical balance (±0.0001 g). First, the unaltered product was weighed. Then the filter was removed and the product was reweighed. This was performed a minimum of triplicate for each brand tested.

Statistical Analysis

For all product comparisons, one-way ANOVAs with Tukey contrasts were used to evaluate all pairwise comparisons presented as the data appeared to meet ANOVA assumptions. All statistical analyses were generated using SAS software Version 9.4 of the SAS System for Windows x64 Systems (SAS Institute Inc., Cary, NC).

Results

Product Characteristics

First, we analyzed the products for differences in product design. The two research cigarettes were 85 mm in length. The cigars varied from 85 mm (Winchester) to 120 mm (Criss Cross). Little cigars weighed approximately the same as cigarettes; however, filtered cigars weighed more than both other products (Figure 1). To break down what contributes to this weight difference, we also weighed the filters and the tobacco plus wrapping separately. Filters of little cigars were similar to cigarettes in terms of appearance (Figure 2); however, the weight was significantly less (Figure 1; $p < .05$). The filters of both brands of filtered cigars contained a clay-like material (Figure 2), mostly likely

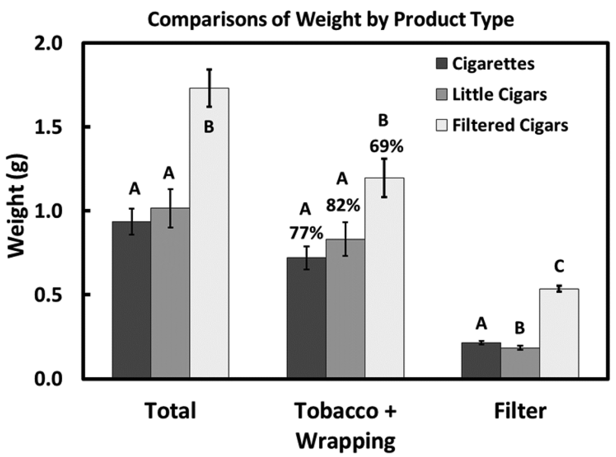

Figure 1. Weight distribution differences in little cigars, filtered cigars, and cigarettes. Two brands of little cigars (Winchester Full Flavor and Captain Black Sweets), filtered cigars (Cheyenne Full Flavor 100s and Criss Cross Full Flavor), and cigarettes (1R6F and 3R4F) were disassembled and weights of the entire cigar or cigarette, of the tobacco and wrapping, and of the filters were recorded. Above the tobacco+wrapping bars are the percentages of the total weight that is accounted for by the tobacco and wrapping for each product. Means with different letters are significantly different ($p < .05$).

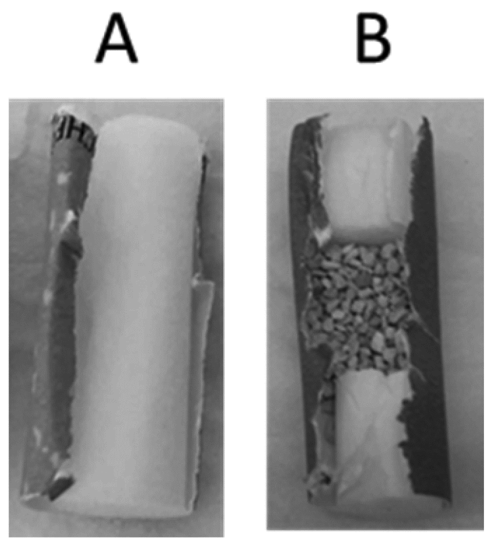

Figure 2. Photographs of the Filter Differences between Little Cigars (A: Winchester Little Cigar) and Filtered Cigars (B: Criss Cross Full Flavored Filtered Cigar).

sepiolite based on previous reports,[6] and weighed significantly more ($p < .05$) than the filters of both cigarettes and little cigars. The tobacco plus wrapping of filtered cigars were significantly heavier ($p < .05$) than little cigars and cigarettes. The smoldering phase was found to account for a greater amount of tobacco combustion in cigarettes than in either cigar product (Figure 4B). Both types of cigars were less vented than cigarettes (Figure 4C).

Carbonyl delivery: ISO Method

The products were analyzed on a per puff basis (Figure 3A, top; Supplementary Table 1). Little cigars resulted in significantly higher levels ($p < .05$) of most carbonyls than cigarettes with exceptions being formaldehyde, which was significantly lower (1.4 ± 0.3 vs. 2.2 ± 0.3 µg/puff), and crotonaldehyde, which was not significantly

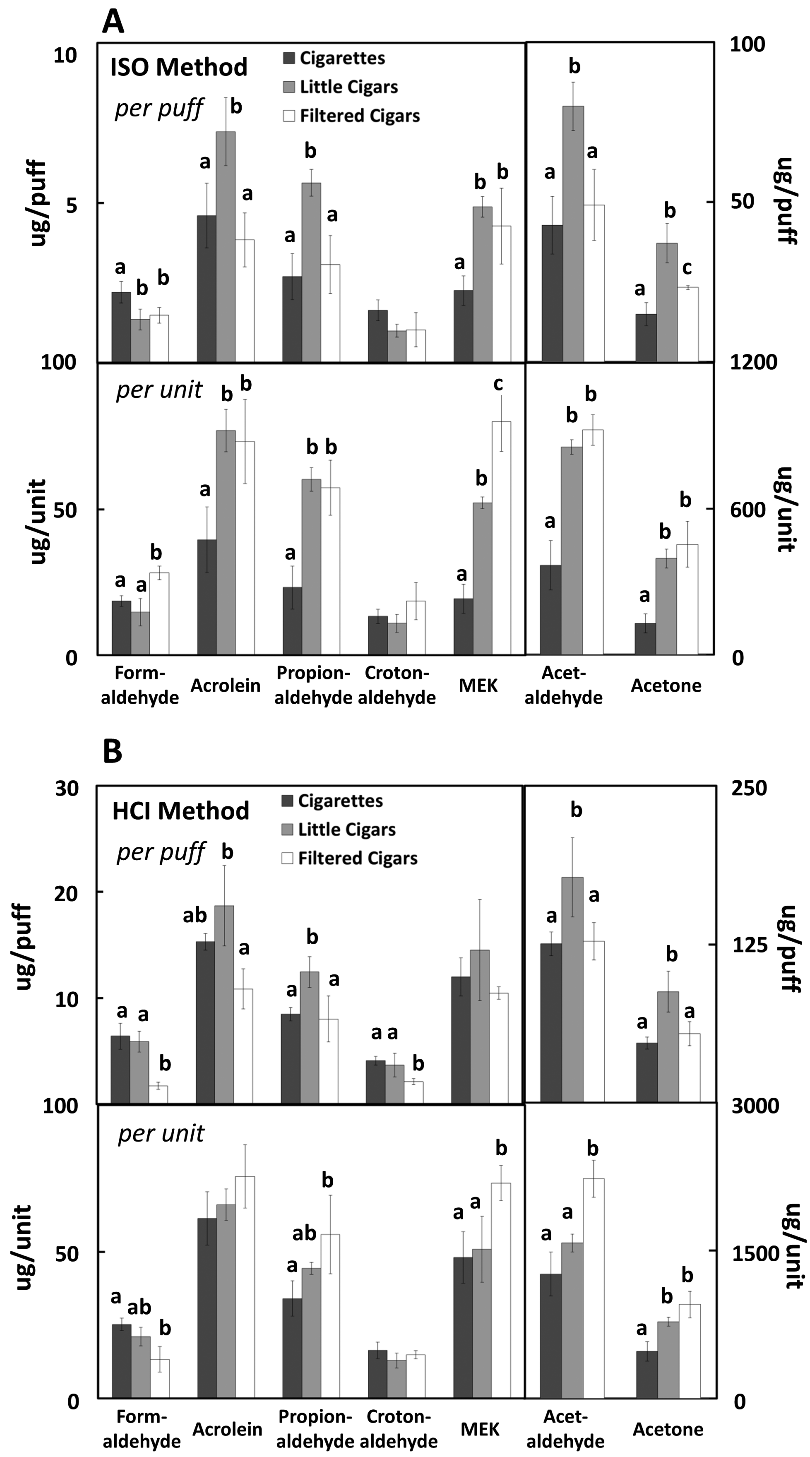

Figure 3. Carbonyl delivery for little cigars, filtered cigars, and cigarettes. Carbonyl output was expressed by puff (top) and by unit (bottom) for both ISO (A) and HCI (B) smoking protocols. Means with different letters are significantly different ($p < .05$).

different. Filtered cigars had similar delivery compared to cigarettes per puff for a majority of the carbonyls; however, formaldehyde was lower (1.5 ± 0.2 vs. 2.2 ± 0.3 µg/puff) while MEK (4.3 ± 1.2 vs. 2.3 ± 0.5 µg/puff) and acetone (23 ± 1 vs. 15 ± 4 µg/puff) were higher ($p < .05$). However, per unit (Figure 3A, bottom), filtered cigars produced significantly higher levels of all carbonyls except crotonaldehyde than cigarettes. Compared to little cigars, filtered cigars produced similar levels per cigar for all carbonyls except formaldehyde (28 ± 2 vs. 15 ± 5 µg/unit) and MEK (80 ± 10 vs. 52 ± 2 µg/unit), which were higher. Puff number (Figure 4A) for filtered cigars (20 ± 4) was significantly greater from both little cigars (11 ± 1) and cigarettes (9 ± 1).

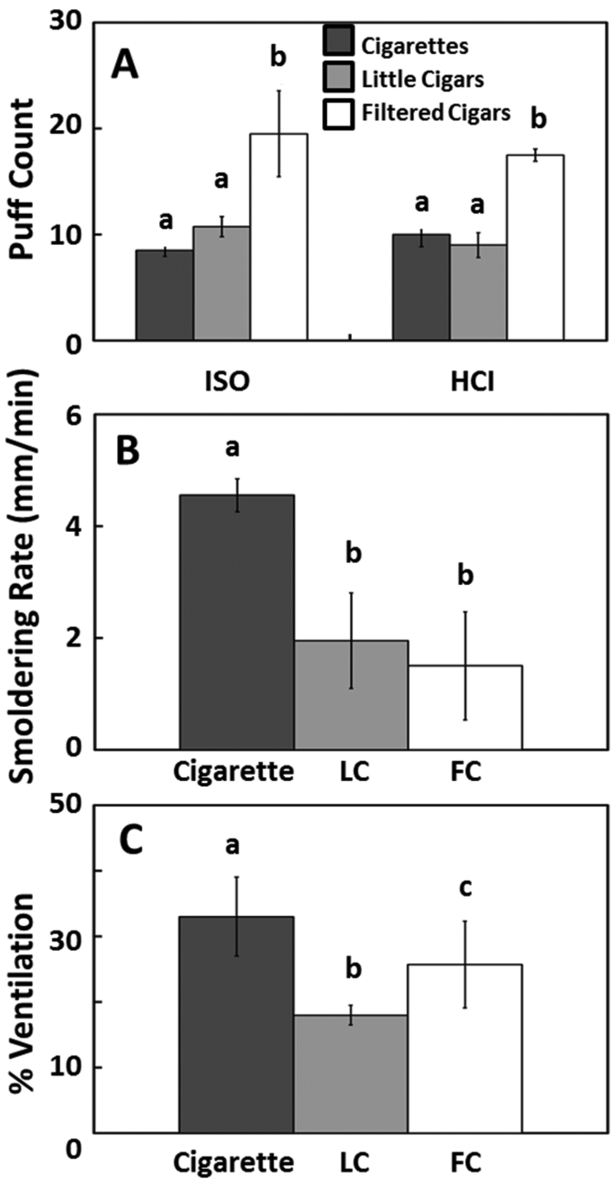

Figure 4. Differences in puff number and smoldering rate for cigarettes and cigars. (A) Puff number between products for ISO and HCI smoking protocols. (B) Smoldering rate between little cigars (LC), filtered cigars (FC), and cigarettes over 3 min after a 35 mL puff. (C) Percent ventilation for all three products tested. Means with different letters are significantly different ($p < .05$).

Carbonyl Delivery: HCI Method

We also assessed carbonyl delivery under the HCI method. When analyzed on a per puff basis (Figure 3B, top; Supplementary Table 2), similar to the ISO method, little cigars showed significantly higher levels ($p < .05$) than cigarettes for propionaldehyde, acetaldehyde, and acetone; however, formaldehyde, acrolein, MEK, and crotonaldehyde were not significantly different. Delivery from filtered cigars using the HCI method was equivalent to cigarettes per puff for a majority of the carbonyls; however, formaldehyde (1.7 ± 0.3 vs. 6.4 ± 1.2 µg/puff) and crotonaldehyde (2.1 ± 0.3 vs. 4.1 ± 0.4 µg/puff) were lower ($p < .05$). Per unit, filtered cigars delivered significantly higher levels than cigarettes for a majority of the carbonyls using the HCI method (Figure 3B, bottom); however, they were not significantly different for acrolein and crotonaldehyde while formaldehyde was significantly lower (33 ± 11 vs. 63 ± 5 µg/unit). Compared to little cigars, filter cigars produced similar amounts of all carbonyls except MEK (183 ± 15 vs. 127 ± 28 µg/unit) and acetaldehyde (183 ± 15 vs. 127 ± 28 µg/unit), both of which were higher from filtered cigars.

Discussion

Our results demonstrated that the delivery of carbonyls from little cigars and filtered cigars can be similar to or greater than that for cigarettes under two different machine-smoking regimens (ISO and HCI methods), with the exception of formaldehyde, for the products tested. Filtered cigars delivered higher levels of acetaldehyde, propionaldehyde, acetone, and MEK than cigarettes, regardless of method, and higher acrolein levels than cigarettes for the ISO method. Little cigars delivered higher levels of acetaldehyde, propionaldehyde, MEK, acrolein, and acetone than cigarettes for the ISO method, but not for the more intensive HCI method, except for acetone. Because individual cigar users vary greatly in their usage behaviors with many falling in between the ISO and HCI methods according to one study,[7] it is likely that users of these products will be exposed on average to equal or greater levels of several toxic and carcinogenic carbonyls per unit smoked than cigarette smokers. This finding is similar to the nicotine differences previously observed between cigarettes and little/filtered cigars.[34] These differences in carbonyl exposure from these products could put the little cigar and filtered cigar smoker at a greater risk for development of tobacco-related diseases compared to cigarette smokers per unit smoked. This information is important when considering the development of regulatory strategies for these new and emerging cigar products. These findings suggest that, if the FDA regulates carbonyl delivery for cigarettes, both little and filtered cigars should be regulated in a similar fashion and perhaps even more stringently based upon a greater delivery of toxic carbonyls.

We found that, as previously noted,[5] little cigars are very similar to cigarettes in weight. However, filter weight was lower in little cigars, indicating a difference in their construction with a greater percentage of the weight being composed of tobacco in these products (82% for little cigars vs. 77% for cigarettes). In addition, we did note that for Captain Black Sweets, the only flavored product tested, there was flavoring in the filter, which was clearly discolored and sweet smelling. The filtered cigars in our study weighted more than similar sized little cigars and cigarettes and greater than reported previously (1.8 g/unit compared to 1.36 g that were reported elsewhere (Figure 1).[35] This is likely a result of the Pennsylvania law that sets the cut-off for little cigars at 4 lbs/1000 cigars (1.8 g/unit),[25] which is different from the federal definition (3 lbs/1000, 1.36 g/unit).[5] Their filters also weighed significantly more ($p < 0.05$) than those of little cigars and cigarettes, maintaining a larger percentage of the total weight of the product (31% vs. 23% (cig.) and 18% (LC)). This difference is likely due, in part, to the addition of heavier materials, such as sepiolite, to the filter, as previously speculated (Figure 2).[6]

On a per unit basis, we found that acetaldehyde delivery was highest from filtered cigars using both the ISO and HCI methods. As acetaldehyde is the most abundant carcinogen in cigarette smoke,[36] this finding is significant, although not fully unexpected as there is much more tobacco in these products and tobacco combustion is the source of most carbonyls in tobacco smoke. On the other hand, little cigars produce more acetaldehyde than cigarettes using the ISO method and similar amounts using the HCI method. Similar to acetaldehyde, propionaldehyde and MEK levels are greater from filtered cigars on both methods while delivery from little cigars was greater using the ISO method, but not using the HCI method. We believe the difference between the methods for the little cigars arises from the differences in ventilation (33% for cigarettes and 15% for little cigars) between the products being corrected for when using the HCI method. Thus, these filtered cigars are potentially more harmful than cigarettes in terms of acetaldehyde, MEK, and propionaldehyde delivery while the little cigars are greater than or similar to cigarettes, depending on the smoking topography and/or ventilation blocking.

Acrolein, a well-known and severe respiratory and cardiovascular toxicant,[11,37] was significantly higher from little cigars and filtered cigars using the ISO method, but not the HCI method. This suggests that ventilation might play a role in the amount of acrolein delivered by these products, similar to acetaldehyde. However, as filtered cigars are not greater using the HCI method like acetaldehyde, it is also possible that the differences in burning that arises from larger puff volumes also affect these levels as HCI has a larger puff volume than ISO. This finding also agrees with previously literature for sheet-wrapped cigars, which found that the acrolein levels were similar between products.[21]

Acetone levels were significantly higher from little cigars and filtered cigars on both methods. The delivery is ~3 times higher than cigarettes using the ISO method and ~2 times higher using the HCI method, showing that the difference decreases using the more intense method. This finding suggests that potential respiratory harm from acetone, which is a known respiratory toxicant, would be greater from these products if smoked similarly to cigarettes. In contrast to these acetone findings, crotonaldehyde was found to not be significantly different per unit for any product based on any smoking regime.

In contrast to the other carbonyls studied here, formaldehyde was found to be lower in filtered cigars than the other two products per unit. This most likely arises from the addition of sepiolite to their filters. Sepiolite can potentially reduce carbonyls by adsorption according to both scientific reports[38,39] and numerous cigarette filter patents.[40–42] In addition to these properties, sepiolite would preferentially remove of particulate phase particles as these would stick more readily to the material than the gas-phase, which is important as formaldehyde is more associated with the particulate phase than any other carbonyl.[43] However, we do want to stress that even with formaldehyde levels being lower, most other carbonyls are greater than from little cigars and cigarettes, thus the lower amount of formaldehyde is not an indication of a safer product.

In addition to affecting formaldehyde levels, sepiolite's adsorption properties could also help explain why the carbonyls do not increase as drastically as expected when considering the large difference in the amount of tobacco being burned and consumed between products. This stands out greatly when considering the quite dramatic difference in puff number between the products (Figure 4A) and the way these products smolder over time (Figure 4B), both of which suggest that smokers are able to combust and inhale more tobacco smoke from cigars over time than cigarettes. The examination by puff accounts for any occasions when a smoker might not smoke any entire unit, as has been noted before for these products.[7] Per puff, filtered cigars deliver similar amounts of carbonyls compared to cigarettes while little cigars deliver much more; thus, these findings also suggest that these products are at least as harmful as cigarettes.

Our study has a few limitations. First, it is important to note that our study is using research cigarettes, which are not for human consumption, as a reference instead of commercial cigarettes; however, these cigarettes tend to be representative of commercial cigarettes as shown by multiple studies.[26,27] For example, Pazo et al.[26] found the 3R4F research cigarette delivered acetaldehyde levels (mean ± SD: 610 ± 170 µg/cigarette) which were comparable to those found in 50 domestic brands of cigarettes (range: 194–1143 µg/cigarette; mean ± SD: 614 ± 194 µg/cigarette) using the ISO method. Comparable results were obtained for other carbonyls as well as for the HCI protocol. The carbonyl levels we obtained for filtered cigars and little cigars were similar, if not higher, than the majority of commercial cigarettes as reported by Pazo et al.[26] Secondly, we only looked at two of each product, limiting the generalizability of the results; however, the findings suggest that these products can be as bad if not worse than cigarettes in terms of carbonyl delivery. Lastly, we did not measure each puff individually. As carbonyl levels have been found to vary between puffs down the cigarette rod,[44,45] more work will need to be done to determine if the same is true for little and filtered cigars.

Altogether, our findings suggest that filtered cigars and little cigars may present a greater risk than cigarettes based upon carbonyl delivery, which supports the FDA's recent regulation of these products[46] and warning letters sent to four of the manufacturers of these products.[47] Multiple studies have shown that little cigar perception is mixed among smokers currently with one study reporting a minority (29.9%) of youth cigar users believing that cigars might be less harmful than cigarettes[48] and another reporting comments about little cigars ranging from "little cigars are much more harmful than cigarettes" to "little cigars do not cause cancer."[49] One last study found that, in general, little cigars are perceived as more favorable than cigarettes regarding potential harm to health.[50] Our findings can be used to combat this mixed perception by informing the public about the levels of some of the carcinogens and toxicants produced by little and filtered cigars. This information can help guide FDA regulation of these combustible tobacco products, specifically in terms of setting appropriate product standards and informing the public of potential toxicant exposures from these products. This paper demonstrates that filtered cigars and little cigars can deliver a higher dose of harmful carbonyls per unit than cigarettes and should be regulated just as, if not even more, rigorously. In addition to helping guide regulation, these data will help to increase our understanding of the cumulative harm among the ever-growing population of cigarette–cigar multi-product smokers when more information becomes available on their usage and smoking behaviors. Further, future studies of deliveries of carbonyls and other toxic agents from the spectrum of brands of little and filtered cigars on the marked are warranted.

Supplementary Material

Supplementary data are available at *Nicotine & Tobacco Research* online.

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Declaration of Interests

JF has done paid consulting for pharmaceutical companies involved in producing smoking cessation medications including GSK, Pfizer, Novartis, J&J, and Cypress Bioscience, and has received a research grant and study drug from Pfizer (not relating to toxicant output from cigarettes or cigars). There are no competing interests to declare for other authors.

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