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Changes in product labelling practices and the use of flavouring chemical additives in vaping products after enactment of statewide flavour legislation

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ABSTRACT

Introduction On 18 May 2020, New York State enacted legislation banning the sale of vaping products with distinguishable flavours (other than tobacco). According to this new statute, vaping products are deemed flavoured if they include a statement, whether expressed or implied, that have distinguishable tastes or aromas other than tobacco. This study aimed to determine how manufacturers responded.

Methods We collected 555 vaping products from daily vapers (238 preban and 317 postban). We compared preban and postban labelling of products for expressed and implied flavour descriptions, graphics and colours. Flavouring chemicals and concentrations were identified using chromatography methods and were compared preban and postban.

Results Analysis of the labels preban and postban did not reveal a change in products with expressed flavoured descriptors (45.8% vs 44.2%) and a minimal decrease in implied descriptors (22.3% vs 14.5%). An increase in products without any descriptors was observed (28.2% vs 37.2%) notably within products from a popular pod brand. The average concentration of eight popular flavourings identified preban was 1.4±2.7 compared with 2.3±3.5 mg/mL ($p<0.001$) postban. No significant changes between individual flavouring concentrations in the most popular refill solutions and pods were found.

Conclusion While a majority of products appeared to remain non-compliant, this study suggests that enactment of legislation on vaping products making expressed or implied flavour claims may result in some manufacturer changes to product labelling including removal of flavour descriptors. However, use of flavouring additives in vaping products appeared not to be impacted by the ban.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Limited data are available to understand the efficacy of recent flavour bans on vaping products in New York State, and none specifically focus on manufacturer responses.

⇒ It is unclear whether changes in product labelling or chemical formulation will be implemented to comply with statutes or regulations.

WHAT THIS STUDY ADDS

⇒ This study reveals that some manufacturers may have removed enforceable labelling characteristics from their products in response to new legislation; however, the majority are in non-compliance as flavoured products continue to be available to consumers.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Jurisdictions contemplating implementing legislation on flavoured vaping products should consider policy that applies to product labelling and additives used to create sensory experience among product users.

⇒ Effective enforcement strategy of existing as well as future legislation is needed. A well-defined list of chemicals permitted in electronic cigarettes would most likely make regulation and enforcement less challenging.

INTRODUCTION

Increased popularity and use of e-cigarettes in the past decade have been greatly influenced by the availability of numerous flavours. Among youth and adult never-smokers (including naïve nicotine users who never smoked a cigarette), flavours are often included as reasons for initiation and continued use,[1–3] and greater numbers of flavours are linked to increased frequency of use.[4] Frequent use also has the potential for addiction, especially with new chemical formulations that include nicotine salts and consequently higher nicotine content.[5 6] Increased nicotine content, driven by widespread use of nicotine salts, has been associated with increased concentrations of flavouring chemicals,[7] likely reinforcing taste appeal and increased sale of these products. Some studies suggest that uptake in e-cigarette usage may lead to future co-use or complete switching to other tobacco products, such as cigarettes.[8 9] Vaping flavoured products is not without potential harm, as several common flavouring additives are cytotoxic,[10–12] lead to increased levels of free radical formation,[13] inflammation[14 15] and impaired immune function.[16] Furthermore, e-cigarette use also increases exposures to heavy metals[17] and other toxicants including carbonyls, volatile organic compounds and tobacco-specific nitrosamines.[18 19] As such, health impacts from long-term inhalation exposure, especially among younger users, are unknown.

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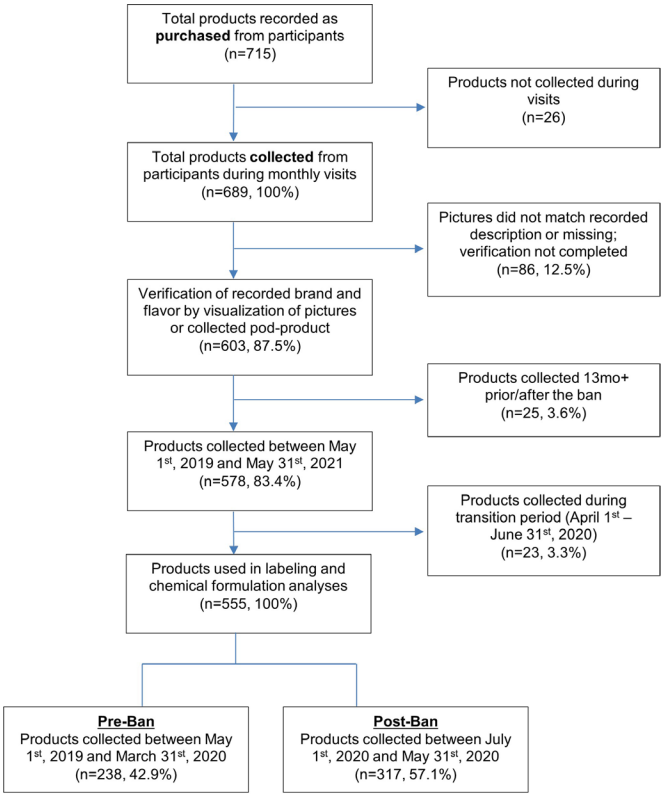

Figure 1 Inclusion/exclusion criteria to determine eligibility of products for comparison. Products collected from participants were included in the final analysis if they were collected 1 year prior to and 1 year after implementation of the May 2020 ban. A transition period of 1 month prior and after, including the month of May 2020, was applied to account for residual product availability. Products collected during this time were excluded.

In response to the youth vaping epidemic, federal, state and local governments or agencies throughout the USA have taken steps to reduce the appeal and influence of flavours by implementing bans centred around the sale of flavoured products. For example, Food and Drug Administration imposed an enforcement policy in 2020 that directed manufacturers to cease the marketing, distribution and sale of unauthorised flavoured cartridges.[20] Some state and local governments, such as in Massachusetts,[21] California[22] and the city of San Francisco,[23] have also implemented statutes and ordinances that contain language prohibiting the sale of vaping products with characterising flavours. Similarly, in New York State (NYS), the sale of vaping products with any statement or claim 'to consumers or the public, whether expressed or implied, that such product or device has a distinguishable taste or aroma other than the taste or aroma of tobacco' is prohibited.[24] Thus, products with expressed (characterising) flavour descriptions (eg, 'Watermelon') or implied (ambiguous, eg, 'Pink Burst') are banned from sale.

The tobacco industry has historically taken steps to circumvent implemented regulations against their products. In 2009, misleading harm reduction descriptors, such as 'light' and 'mild' were banned from package labelling by the Family Smoking Prevention and Tobacco Control Act.[25] In response, the tobacco industry emphasised package colours, such as gold, blue and silver to continue implying the differences between cigarettes.[26] In the same legislation, characterising flavours other than menthol in cigarettes were banned. However, the individual flavouring chemical additives were not subject to regulation. Today, levels of cocoa and chocolate ingredients, for example, remain consistent in cigarette formulations among several top manufacturers.[27] Similar actions should therefore be expected with current flavour bans on e-cigarette liquids. We hypothesise that manufacturers may simply change product labelling by removing or modifying flavour descriptors, while not altering chemical formulations.

To identify potential implications of proposed and future flavour bans, this study aimed to provide several examples of industry response to existing legislation, specifically the NYS flavour ban, by evaluating vaping product labelling practices and chemical formulations. Comparisons between products purchased before and after enactment of the ban on 18 May 2020 ('pre-post analyses') will ultimately help inform tobacco policymakers who seek to develop, refine and implement effective flavour bans to reduce vaping among youth.

MATERIALS AND METHODS

Study participants

This study included 93 participants from an ongoing recruitment cohort of daily e-cigarette vapers residing in and around Buffalo, New York. Participants were assessed during an anticipated total of 12 monthly sessions and were instructed to bring all current e-cigarette devices and liquids, including those used between visits. During each session, pictures were taken, and aliquots of refill solutions and disposable cartridges or pod devices were collected with consent. Date of collection, brand, labelled flavour descriptors and general purchase location (ie, local vape shop, online, etc) as reported by study participants were recorded, and all liquids were stored at 4°C until analysis.

Collection of vaping products

A total of 689 liquids (refill and pod systems combined) were collected, with an average of 25.2±11.7 products per month. Each study participant provided on average 6.0±4.8 products. After confirming staff records of brand and flavour described by participants compared against photos taken during the time of session, 86 (12.5%) products were excluded due to mismatches in recorded flavour descriptor and image, non-labelled bottle images or missing images. Liquids were further narrowed to those collected 12 months prior to enactment of the flavour ban on 18 May 2020, and 12 months after. Any product collected between 1 April and 30 June 2020 was also excluded as vapers may have purchased more flavoured products than usual to stock up in anticipation of the impending ban. A total of 555 (80.5%) vaping products remained for analyses; 238 (42.9%) preban products (May 2019–March 2020) and 317 (57.1%) postban (July 2020–May 2021). (figure 1).

E-cigarette label analysis

Three main product traits were evaluated using a laboratory-developed standardised closed questionnaire (online supplemental analysis 1, online supplemental table S1) and photos taken during participant sessions. Briefly, any text or descriptive language on the label was critiqued for expressed (eg, 'Strawberry' or 'Watermelon Lime') or implied (eg, 'Pink Burst' or 'Arctic Air') flavour descriptors other than tobacco. Descriptors that indicated tobacco flavour were recorded as not containing any flavour descriptors. A published e-cigarette liquid flavour wheel[28] was used as a non-exclusive reference, specifically for expressed flavours. Primary label and bottle colours were each reviewed and assigned according to a laboratory-developed colour scale[29] (online supplemental analysis 1, online

supplemental figure S1). Finally, the label graphics were evaluated for expressed or implied images other than tobacco, as well as primary colours. An example of the identification of these three traits in the product image is provided in online supplemental analysis 1 and online supplemental figure S2. Three independent and trained reviewers selected responses as defined by the closed questionnaire for all eligible vaping products. The majority response (at least two reviewers agreed) for each trait assessment was used in the analysis. Detailed explanation about this process, validation, data review and analysis are included in online supplemental analysis 1.

Sample preparation and chemical analysis

Collected liquids were gently mixed for 1 hour prior to preparation, using a vertical multifunction rotator (Grant Instruments, Shepreth, UK). For pod cartridges and smaller disposable devices, liquid was extracted either by centrifuge or manual deconstruction. Liquids were independently prepared for two analytical assays. First, qualitative analysis to tentatively measure the number of flavouring chemicals in each liquid was prepared by adding 10 µL of each liquid to 1 mL of dichloromethane, in triplicate. Second, quantitative measurements of eight common flavouring additive concentrations were prepared by adding 30 µL of each liquid into 3 mL of a methanol-based extraction solution (with 1 mg/mL each of five internal standards).

Qualitative identification of flavouring chemicals in each liquid was performed on an Agilent 7890B/5977A GC/MS with a DB-624 UI (30 m, 320 µm ID, 0.25 µm film thickness) analytical column, using parameters described previously[11 30] and reported in detail in online supplemental analysis 2. Tentative flavouring chemical identifications were made using a combination of known spectral libraries, including laboratory derived, Flavours and Fragrances of Natural and Synthetic Compounds (third edition, Mondello, Wiley, Hoboken, New Jersey, USA) and 2017 NIST Mass Spectral Search Programme (NIST17, v2.3, NIST Mass Spectrometry Data Centre, Gaithersburg, Maryland, USA). Flavouring chemicals specifically were determined by matching identified Chemical Abstract Service (CAS) numbers to known taste and/or odour descriptors from an online flavouring database[31] and those not considered to be vaping flavour additives (eg, toluene) were excluded. Propylene glycol and vegetable glycerin, while associated with a flavour, were also removed. Complete details on the process are included in online supplemental analysis 2.

Concentrations of benzaldehyde (fruity, cherry), benzyl alcohol (fruity), ethyl maltol (sweet), ethyl vanillin (sweet, vanilla), furaneol (caramellic), maltol (sweet), menthol (cooling, minty) and vanillin (sweet, vanilla) were measured using a 7890B/7250 GC/Q-TOF equipped with a PAL RSI 120 autosampler (CTC Analytics, Zwingen, Switzerland) and DB-624 UI (30 m, 250 µm ID, 1.4 µm film thickness) analytical column (Agilent Technologies, Santa Clara, California, USA) using a fully validated method. Calibration procedures and method parameters have been previously described elsewhere.[32]

Statistical analysis of labelling practices and product chemistry

Descriptive statistics including the type of products (refillable solution or pod system) collected and frequency of brands purchased preban and postban were compared. Primary analysis of product labelling included comparing the number of vaping products with expressed, implied or no flavour descriptors collected preban and postban. To understand the impact of flavour expression through colours, the number of products with predominate colours other than white, black or absence of colour (clear) on labels and bottles (or disposable pod devices or cartridges) were compared with those that were predominately not coloured. Differences in graphic representation of flavour descriptors and colours were also compared. All comparisons were performed using Wald χ^2 tests in SPSS (V.27; IBM). For product chemistry, the average number of identified flavourings were compared between preban and postban products. Additionally, the average concentration among all eight flavouring chemicals, as well as within each individual chemical, was compared. Mann-Whitney non-parametric t-tests were performed for each comparison in GraphPad Prism (V.9.1.0, San Diego, California, USA) and significance was defined at $p<0.05$.

RESULTS

Product descriptive characteristics

Among the products collected prior to the 18 May 2020 flavour ban, 179 (75%) were e-cigarette refill solutions and 59 (25%) were pod systems. In comparison, 206 (65%) postban products were refill solutions, while 111 (35%) were pod systems. Within preban products, 62 individual brands were identified. Likewise, postban products included 66 individual brands. Of the total products collected before the ban, 21% were from unique brands (only one to two products per brand) (online supplemental figure 1). Over 30 products (13%) were collected were from JUUL. The frequency of products collected from unique brands was similar among postban products (16%), whereas two brands accounted for 39% of all products collected after the ban (online supplemental figure 1). Among these two postban brands, 93 products were from the podstyle brand Hyde and 32 were from a local refill solution brand (Yeti Vape).

Labelling practices

Before enactment of the ban, 68.1% of products contained either expressed or implied flavour descriptors. This decreased slightly postban where 58.7% of products contained a flavour descriptor. The use of expressed flavour descriptors was nearly identical between preban and postban products (45.8% vs 44.2%), while the use of implied descriptors decreased slightly in postban products (22.3% vs 14.5%, $p=0.028$) (table 1). The lack of any flavour descriptor (expressed or implied) increased notably among postban products (28.2% vs 37.2%, $p=0.012$). Use of coloured labels also remained consistent (49.2% vs 48.9% preban vs postban), while an increase in bottle (or device) colour increased after the ban (13.0% vs 30.3%, $p<0.001$). Overall, it was apparent that graphics were not commonly used to express or imply flavours. Nearly 75% of products did not contain a graphic, or the graphic was not representative of a flavour (69.7% and 77.9% preban and postban). Among a small subset of products with flavour-related graphics, a significant reduction in implied graphical images was observed postban (table 1). Likewise, the graphics were predominately uncoloured in preban and postban products (58.4% and 67.5%), although a significant reduction in the presence of coloured graphics postban was noted (41.6% vs 32.2%, $p=0.031$).

Product chemistry

On average, preban products contained 13.9±8.0 flavourings, which decreased among postban products (10.0±6.6, $p<0.0001$) (figure 2A). A total of 342 detections of the eight measured flavouring chemicals were found across 78.2% of preban products. The detected concentrations averaged

Table 1 Comparison of labelling practices in products collected preban and postban

Product characteristic	Flavour descriptor*			Graphic flavour descriptor†			Primary‡ label colour			Primary bottle colour			Graphic primary colour		
	Preban	Postban	P value	Preban	Postban	P value	Preban	Postban	P value	Preban	Postban	P value	Preban	Postban	P value
Expressed§ flavours, n (%)	109 (45.8)	140 (44.2)	0.792	47 (19.7)	54 (17.0)	0.493	–	–	–	–	–	–	–	–	–
Implied flavours¶,n (%)	53 (22.3)	46 (14.5)	0.028	24 (10.1)	15 (4.7)	0.030	–	–	–	–	–	–	–	–	–
No expressed or implied flavour indicated, n (%)	67 (28.2)	118 (37.2)	0.012	166 (69.7)	247 (77.9)	0.024	–	–	–	–	–	–	–	–	–
Presence of colours**, n (%)	–	–	–	–	–	–	117 (49.2)	155 (48.9)	1.000	31 (13.0)	96 (30.3)	<0.001	99 (41.6)	102 (32.2)	0.031

Totals do not add to 100%. Less than <5% of product images were unclear and illegible. Data not included in the table.
*Contains wording to suggest flavour, other than tobacco, independent to the brand or manufacturer name.
†Graphic refers to any image on the label or bottle independent of the brand or manufacturer logo.
‡Primary determined as the predominate colour observed in each the label, bottle and graphic.
§Expressed flavours refers to characterising or known flavour descriptors other than tobacco, such as 'Watermelon', or combination of established flavours, such as 'Watermelon Lime'. Expressed graphics included overt flavour images, such as an orange or pineapple.
¶Implied flavours refers to ambiguous language other than brand or manufacturer name that suggests flavour name, such as 'Pink Burst'. Implied graphics included images that may be perceived as contributing to flavour, such as a leaf (mint), snowflake or ice cube.
**Refers to colours as 1–14 on colour scale (online supplemental analysis 1, online supplemental figure S1). Data from this analysis were imputed as binary (coloured or not coloured). Products where colours were not present are not reported here. P value remains the same as presence of colours on products.

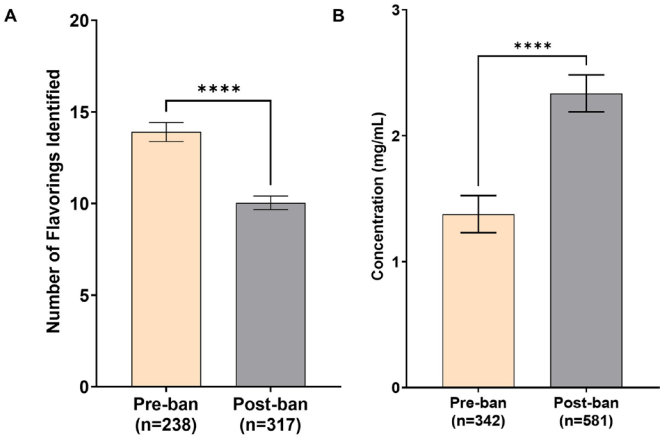

Figure 2 Comparison of the average number of identified flavouring chemicals (panel A) and average concentration among eight flavouring chemicals (panel B) in vaping products collected preban and postban. ****P<0.0001. Error bars represent SEM.

1.4±2.7 mg/mL (figure 2B). The most frequent detections were benzyl alcohol (fruity) (34.3%), furaneol (caramellic) (26.9%) and maltol (sweet) (21.9%) (figure 3A). In postban products, 581 total detections in 83.9% of products had a significantly higher average concentration of 2.3±3.5 mg/mL, p<0.0001 (figure 2B). Benzyl alcohol was again identified most frequently (35.7%), as was ethyl maltol (sweet) (30.4%), furaneol (29.5%) and vanillin (sweet, vanilla) (31.7%) (figure 3A). Despite differences in overall concentration of the eight flavourings, only benzaldehyde differed significantly (p=0.011) when compared individually (figure 3B). While amounts of this chemical were slightly lower among postban products, benzaldehyde was also identified less frequently (14.5% vs 4.4% preban vs postban) (figure 3A).

Identical brands and flavours collected preban and postban

To explore specific examples of label practice and product chemistry changes by manufacturers, 13 of the most frequent brands and their flavours collected both preban and postban were compared (eg, Hyde, 'Lush Ice' n=6 preban, n=6 postban). This sample set comprised 21% and 20% of the total brands collected preban and postban, respectively. The majority of products contained identical labelling for each flavour collected before and after the ban (online supplemental table 1). Three brands (7 Daze, Juice Head and Cloud Nurdz) incorporated new graphic elements to labels after the ban; however, expressed flavour descriptors did not change. A substantial difference in labelling practice was observed in a single podstyle brand (Hyde) where preban pods contained expressed descriptors, while a noticeable absence of flavour descriptors emerged in postban products.

Chemical composition did not vary after the ban in most brands and their flavours. For example, Yeti Vape contained similar numbers of flavouring chemicals within each flavour ('Beast Cake', 'Crunchy Black' and 'Chupacabra') and concentrations of ethyl maltol and vanillin were consistent (online supplemental table 1). Hyde, although differing in labelling, had similar numbers of flavourings and concentrations of ethyl maltol and menthol after the ban. In some brands and associated flavours (Keep It 100 and Pod Juice), the number of flavourings identified differed after the ban, yet concentrations of five flavourings chemicals remained the same.

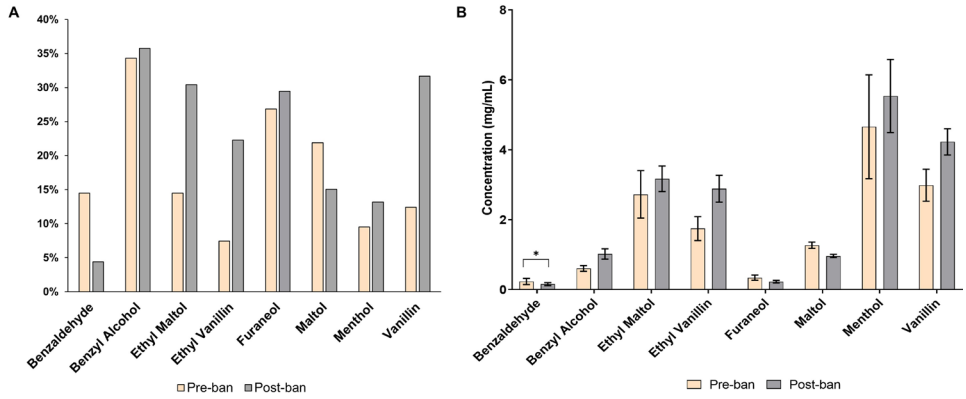

Figure 3 Comparison of the frequency of eight flavouring chemicals identified (panel A) and average concentration of eight flavouring chemicals (panel B) in vaping products collected preban and postban. *P=0.011. Error bars represent SEM.

DISCUSSION

Our study attempts to provide evidence on the effects of the NYS flavour ban by offering examples of manufacturer response. Studies published previously have relied primarily on sales data and self-reported usage, underlining vendor practices only. To our knowledge, this is the first study to examine the effects of flavour bans with objective measures by directly assessing popular vaping products purchased and used by consumers.

Our results revealed that expressed flavour descriptors were largely not removed from vaping products and that there was a minimal reduction in the use of implied flavour descriptors after enactment of new legislation. This suggests most products that had flavour claims before the ban likely continued after. This was further evident when comparing specific brands and their flavours purchased before and after the ban. With exception of one brand (Hyde), all products contained the same expressed or implied flavour descriptors. This finding may be largely explained by overall non-compliance from either the manufacturer or the vendor and would require further investigation using a different study design. Interestingly, we observed an increase in products without any flavour descriptors after the new legislation was implemented. This finding might suggest adherence to the law for some product manufacturers by supplying only tobacco-flavoured products. However, we cannot confirm this since our methods did not differentiate tobacco flavours from those products not containing flavour descriptors.

Another important finding was a sharp increase in the percentage of coloured bottles or pod devices collected after the new legislation was enacted. This finding may be explained by a large proportion of Hyde products collected postban. Striking labelling changes among Hyde were observed where preban products with models containing flavour descriptors printed directly on the device (eg, 'Original' and 'Slim') were seemingly replaced with newer models (eg, 'Edge', 'Colour' and 'Curve Plus'), which did not contain any flavour descriptors. Instead, these models feature unique colours with fading or blending patterns. Consistent colour patterns were found across several of these models, suggesting intentional implied flavour identification for consumers.

By regulating product flavour claims, without specified regulations on the product chemistry, manufacturers may add additional flavourings or increase concentrations of existing chemicals in their formulations. For example, we observed an increase in the frequency of postban products containing ethyl maltol, ethyl vanillin and vanillin. These flavourings impart sweet, fruit-like, creamy and vanilla flavours,[31] suggesting products may still provide similar sensory experiences to consumers, including youth. Importantly, products with flavour claims of tobacco may continue incorporating these flavourings as ingredients to improve otherwise lesser appealing tastes. While a significant increase in the average concentration of eight popular additives after the ban was also noted, this was less than 1 mg/mL difference. Between individual chemicals, differences were not significant. Conversely, we identified fewer numbers of flavouring chemicals among postban products. This finding should be taken with caution, given the tentative methodology used to gather these results. Overall findings of product chemistry indicate manufacturers are likely not changing their formulations, meaning flavouring chemicals continue to be present, even if labelling changes. This is further confirmed by focusing on specific examples of the most popular brands and their flavours that were collected preban and postban. Most products contained similar numbers and concentrations of flavouring chemicals. Even within Hyde flavours, which we previously recognised to have changed labelling practices, concentrations of several flavourings were consistent.

Findings here are in accordance with previously reported outcomes from legislation in New York City, which in addition to the Family Smoking Prevention and Tobacco Control Act, banned all flavoured tobacco products, including cigars (but excluding e-cigarettes).[33] Initial reports suggested a decline in flavoured product availability.[34] However, a later study indicated significant challenges with monitoring policy compliance because of increasing proportions of products with ambiguous flavour descriptors, such as 'fusion' and 'blue ocean mist'.[35] Despite enforcement in 2010, non-cigarette products with explicit and ambiguous descriptors were recognised to be widely available in stores many years after the ban's implementation.[35] More recently, several reviews of flavoured e-cigarette bans have reported similar availability of flavoured products among multiple venues and online retailers in San Francisco[36] and Massachusetts.[37] Conflicting data also suggest high compliance by some vendors in San Francisco.[38]

Lack of enforcement of the NYS policy likely influenced the observations made from this study, such as overt non-compliance. Without strict enforcement, manufacturers may continue supplying flavoured products to retailers, who subsequently continue selling such products. For example, 47 retailers across NYS were issued cease and desist letters in December 2020,[39] underscoring the sustained availability of flavoured products. Three manufacturers were also cited in July 2020 for violations of online sales.[40] Our study did not assess enforcement practices,

however, and the efficacy of enforcement is not known. Furthermore, the ascertainment of flavoured products by enforcement officers is vague where the statute suggests enforcement by packaging claims (a product is 'presumed to be flavoured if a product's retailer, manufacturer or manufacturer's agent or employee has made a statement or claim' of distinguishable tastes or aromas other than tobacco).[24] Future studies to evaluate enforcement in NYS are possible, as compliance and penalties are reported to the governor and legislature annually.[41]

Existing policies on flavoured e-cigarette products provide important initial steps in reducing availability to youth and other countries, such as Denmark and Finland have implemented similar restrictions.[42 43] Yet improvements are necessary to enhance efficacy. Enforcement of policies based on flavour claims may be more challenging given manufacturers' abilities to adapt their products. To prevent changes in packaging, such as marketing through colours observed with this study, additional language prohibiting expression of flavours through 'text, colour and/or images'[23] could close such loopholes. Furthermore, requiring plain packaging similar to proposed cigarette packaging legislation[44] may also improve efficacy. This strategy is proposed in Finland[43] and is current policy in Denmark.[45] Complementary approaches could include regulating flavouring chemicals themselves at the ingredient level not just as characterising/distinguishable flavours, such as by listing only those additives that are permitted, as previously recommended[46] and as proposed in the Netherlands.[47] In Canada, a three-pronged approach to controlling flavoured vaping product appeal has been proposed.[48] In addition to restricting vaping products with marketed flavour claims (except tobacco, mint and menthol), all sugars and sweeteners, as well as most chemicals that impart flavouring properties or enhance flavours (other than tobacco, mint and menthol) would be prohibited. The proposal also prescribes sensory attribute standards, which mandate that vaping products cannot produce sensory perception of flavour (other than tobacco, mint and menthol) through the olfactory, gustatory or trigeminal chemosensory systems.

Limitation

We recognise several limitations with this study. First, we cannot draw conclusions about apparent non-compliance by manufactures since our study design cannot differentiate between vendor and manufacturer behaviours. Likewise, we did not assess enforcement efforts by NYS officials. These factors likely contributed to the availability of products that our participants were able to purchase. We did not record specific locations or dates of purchase and thus cannot confirm all products were purchased in NYS or that postban products were purchased after 18 May 2020. However, participants were asked for the general location of e-cigarettes purchased during each session (ie, local vape shop, online, etc). No significant differences were observed in self-reported purchasing habits evaluated 1 month before and after the ban, suggesting the differences in product labelling and chemistry observed in this study were not from shifts in purchasing venues (eg, switching to online purchasing). Furthermore, online sales of vaping products to private residences were prohibited in NYS as of 3 July 2020.[49]

The image analysis was intended for product identification and not for systematic packaging analysis. As such, images captured only the front and back parts of product bottles and flavour descriptors located elsewhere may have been missed. Likewise, for pod style systems without flavour descriptors, expressed or implied flavours may have been present on external packaging not provided during the participant's session. Additionally, while informative, results of the qualitative analysis should be treated cautiously. Measuring the presence of chemicals is dependent on the sensitivity of the instrument's detector during the time of the analysis. While control samples are included to measure instrument performance, the use of standardising methods, such as internal standard, are not applied here. As such, data used in this study were acquired across several years. Likewise, flavouring identifications are tentative as shifts in retention times may lead to differences in identification over time, though the use of several libraries can reduce inconsistencies. Given these limitations and the absence of studies that make similar comparisons in e-cigarette products, our conclusions should be confirmed with subsequent studies.

CONCLUSIONS

Results of our study indicated most products were non-compliant with NYS policy where expressed or implied flavour descriptors remained after the ban. Some significant changes to product labelling practices were observed, particularly with the Hyde brand, as expressed and implied flavour descriptors were removed with more products using colours to express flavour instead. Conversely, limited changes in chemical formulations were noted. More importantly, individual flavouring chemical concentrations did not change significantly over time. These results suggest some manufacturers may be changing labelling practices only without removing flavouring chemicals from the product. These results may be helpful in predicting industry tactics to keep their flavoured vaping products on the market and for regulatory agencies to consider comprehensive and multilevel regulation of flavoured vaping products.

Contributors MLG contributed to the conception of the work. MKP, ACB, NJL, RJO and MLG contributed to assay development. LMK and CDM contributed to product and image collection. MKP, ACB and ALS ran all experiments. MKP, ACB, NJL and BES contributed to image analysis. MKP and RJO contributed to data analysis. MKP, ACB, NJL, RJO and MLG drafted the manuscript. All authors approved the final version of the manuscript. MLG has full access to all study data and takes responsibility for the overall content and integrity of the data and accuracy of the data analysis.

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Patient consent for publication Not applicable.

Ethics approval This study involves human participants and was approved by Roswell Park Institutional Review Board, under number I-70618. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. Data are available on reasonable request. Data contain vaping product information including brands and flavours collected from deidentified participants. Product images, flavouring chemical identities and concentrations are available on request.

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