New Zealand Tobacco Product Testing

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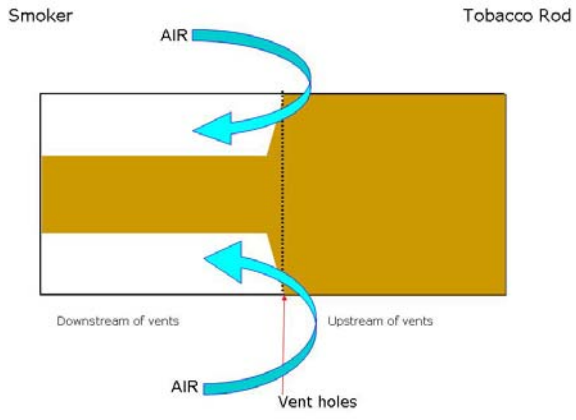
Introduction

Cigarette smoke is an aerosol, which contains more than 4,000 different chemicals. Some of the harmful substances found in cigarette smoke include nitrosamines, tar, pesticides, carbon monoxide, volatile organic compounds, metals, carbonyl compounds, and polycyclic aromatic hydrocarbons. Tobacco-specific nitrosamines and polyaromatic hydrocarbons have been linked to causing lung cancer in smokers.

Cigarette design plays a major role in determining the yields of tar, nicotine, and carbon dioxide measured in cigarette smoke using machine smoking tests. Cigarette design has changed over time in response to growing health concerns from consumers, who desire lower emissions levels. Manufacturers have taken actions including the introduction of filters, ventilation, and changing paper porosity.

Filtered cigarettes became popular in the early 1950's as the demand for lower smoke yields grew, following the initial reports of lung cancer associated with smoking. Today, filtered cigarettes represent the majority of the market. Relative to unfiltered cigarettes, filters can reduce the machine yields of tar and nicotine 40-50%. Cigarette filters are made from cellulose acetate filaments. The smoke removal efficiency and filter pressure drop are determined by the total surface area of the filter fibers. The weight (packing density), number of fibers, fiber diameter and cross-section are all determinants of the filter efficiency. The filter's smoke removal efficiency is directly related to the filter pressure drop.

The primary method now used by cigarette manufacturers to achieve lower machine-measured yields is to add ventilation holes to cigarette filters. Ventilation holes appear as a ring of tiny perforations that circle the filter end of the cigarette. This design feature allows air to enter the holes, which dilutes the tobacco smoke coming from the mouth end. This reduces the effective size of the puff at the coal of the cigarette, also reducing the amount of tobacco which is consumed. Smoke yields are reduced roughly in proportion to the degree of filter ventilation. Puff count is also changed by filter ventilation. The amount of the tobacco rod burned during a puff is reduced, since ventilation reduces the puff volume at the cigarette coal.



Cross-Section of a "low tar" cigarette filter, smoked with no vent holes blocked.

The air permeability of cigarette paper results from naturally occurring pores in the paper. The static burn rate of the cigarette and the degree of ventilation of the tobacco rod are both dependent on paper permeability. Another process that depends on paper permeability occurs during puffing. Some low molecular weight gases diffuse through the cigarette paper. Yields of all smoke constituents are reduced with increased paper permeability. When the paper's permeability increases, air enters the tobacco rod directly, without passing the coal. Similarly to the effects of filter ventilation, this reduces the puff volume at the coal when paper permeability increases.

In general, increased tobacco weight results in increased smoke yields. However, there are competing factors at work in this area. Longer tobacco rods and rods with higher packing density can act as filters through condensation of the smoke as it forms. More filtration is seen with increased diameter due to decreased smoke velocity. Additionally, the pressure drop may be increased by greater tobacco weight, which will cause the ventilation levels to increase. These competing factors make it difficult to predict the exact effects that increasing tobacco weight will have on smoke yields.

Protocols have been developed in order to systematically test cigarette smoke yields through machine testing. Filter ventilation is successful in lowering yields when cigarettes are smoked by machines. However, this is not the case when the cigarettes are smoked by people. People knowingly and unknowingly subvert this design feature by blocking the ring of holes by a number of different methods. When the holes are blocked, they no longer allow air to pass through to dilute the inhaled smoke. Smokers are easily able to compensate when smoking ventilated cigarettes, which makes the cigarette an elastic system. There are a number of ways in which the smoker can increase the amount of smoke intake from each cigarette:

A. Increase total volume of smoke taken per cigarette
    a. Take larger puffs
    b. Take more puffs
        i. Smoke to a shorter butt length
        ii. Puff more frequently
B. Increase concentration of smoke per puff
    a. Block vents on heavily vented cigarettes with lips, fingers, or tape
    b. Increase puff velocity
    c. Remove filters

(Kozlowski LT, O'Connor RJ. Cigarette filter ventilation is a defective design because of misleading taste, bigger puffs, and blocked vents. *Tobacco Control* 2002)

Since the machine testing protocol does not accurately represent human smoking behaviors, an alternate protocol is also used to test the cigarette yields under "intense" smoking conditions. This method uses a larger puff volume, and a shorter interval between puffs than the ISO method.

Documents which are now available reveal that tobacco industry research found that smokers compensate for the lower nicotine levels in low-yield cigarettes by smoking more intensely. They also found that the levels of tar and nicotine smokers receive are substantially greater than the machine-smoked yields that were reported to consumers and regulators. The tobacco industry knowingly capitalized on the limitations of the smoking machine protocol used to report TNCO yields to consumers and regulators. Cigarettes were promoted as "low yield" when they only produced low yield under unrealistic smoking conditions.

Some countries have limited the maximum allowable levels of TNCO emissions, and many countries require the levels to be printed on cigarette packaging. Article 11 of the FCTC calls for information on relevant constituents and emissions to be printed on cigarette packaging. Labeling packages with this information is troublesome, because TNCO emission numbers are misleading to consumers, who do not realize that these numbers are not related to the level of risk related to using a particular product. For these reasons, scientific bodies support replacing emission numbers with descriptions of cigarette emissions, constituents, and their health effects. This way, consumers may better understand the true risk associated with smoking regular as well as low emission cigarettes.

Methods

Overview

This report presents data on the design and physical characteristics of brands purchased in New Zealand. Characterizing product design and physical features can be useful in providing context for ISO smoking machine yields.

Brand identification and selection. Eleven leading cigarette varieties available for sale in New Zealand were identified and are listed below (Table 1). Cigarettes were purchased in 3 locations in August 2007 (a Wellington central city supermarket, a Wellington suburban supermarket and a store in a rural town in Wairarapa). Cigarettes were shipped via common courier to Roswell Park Cancer Institute, where they were catalogued and stored. One pack of each variety was set aside for physicals testing. Four packs of each variety were set aside for emissions testing.

Benson Hedges Special Filter	Winfield
Dunhill Filter	Holiday Extra Mild
Holiday Menthol Mild	Holiday Special Filter
Horizon King Size	Marlboro Lights
Pall Mall	Rothmans King Size
	Benson Hedges Golden

Storage and conditioning. Packs were stored at -20ºC until analysis in a restricted-access walk-in freezer. Cigarettes were conditioned at 22ºC and 60% relative humidity in an environmental chamber (Parameter Generation Control, Black Mountain NC) for 48 hours prior to testing, in accordance with ISO 3402:1999. Room conditions averaged 22.3°C (standard deviation 3.4) and 16.2% (standard deviation 6.7) relative humidity at time of testing.

Measurement Protocols

Design features and physical properties. Physical and design testing was completed in September 2007. Parameters assessed in the current study are described briefly below (Table 2). More detailed measurement protocols are available by request.

Design Feature	**Units**	**Measurement**	**Explanation**
Filter Ventilation	%	5 cigarettes Borgwaldt KC-3	Percentage of smoke that is diluting air when a smoker takes a puff. Cigarettes with lower standard tar yields have proportionately more vents; compensation can be accomplished by blocking vents. Cigarette elasticity is highly dependent on filter ventilation. Overall, filter ventilation impacts smoke composition, filter efficiency, and physical

			properties of smoke.

Pressure Drop	mm water	5 cigarettes Borgwaldt KC-3	Pressure drop is the power required to move air through a whole cigarette. Pressure drop is a component of draw resistance, which contributes to smokers' acceptance. Draw resistance of a cigarette refers to the resistance of the tobacco rod, and filter element, if present, to air flowing there along. Smokers find excess or insufficient resistance to draw unacceptable.
Paper Porosity	mL/cm ^{2}/min	5 replicates on 5 papers Cerulean PPM 1000M	Measure of movement of air through the wrapping paper surrounding the cigarette. Porosity is directly related to burn rate and inversely related to levels of volatile toxic agents.
Cigarette Length	mm	Digital calipers	Cigarettes are often classified by their length as Regular/Short (70-72mm), King size (80-85mm), long (100mm), or super-long (120mm).
Tobacco Rod Length	mm	Digital calipers	Proportion of cigarette length filled with tobacco. Less tobacco available for burning, generally, leads to lower yields.
Filter Length	mm	Digital calipers	Proportion of cigarette length comprised of filter. Longer filters trap more particles, but tend to be harder to draw on.
Cigarette Diameter	mm	Digital calipers	Smaller diameter leads to less tobacco being burned and to increased oxygen availability during combustion, leading to lowered levels of tar, nicotine, and other particulates. Cigarette diameter can also influence burn rate and change the number of puffs for a single cigarette.
Tipping Paper Length	mm	Ruler	Tipping paper attaches the filter tip to the tobacco rod. The portion that extends beyond the filter over the tobacco column is called the 'overwrap.' A longer overwrap generally means that less tobacco will be burned in the ISO test, as the stopping point is overwrap plus 3mm, hence lower yields.
Ventilation Holes	N, mm	Ruler	Number and placement of ventilation holes relative to mouth end. Holes or perforations are formed in the tipping paper to allow cool atmospheric air to enter the tobacco smoke stream. The size and spacing of the holes or perforations in the tipping paper determine its permeability to the air and effect the degree of dilution of the smoke with atmospheric air. It is desirable to provide a constant permeability or dilution for particular types or brands of smoking products.
Tobacco Filler Weight (Wet, Dry)	g	Contents of 5 cigarettes Mettler Toledo MW3150	Levels of smoke constituents are directly related to the amount of tobacco that is burned. In the past, expanded tobacco has been used to reduce the amount of tobacco in the cigarette rod and thus,

			reduce emissions.
Tobacco Moisture	%	Mettler Toledo MW3150	Moisture is determined as the percent change in weight of tobacco in response to heat at 125ºC. Commonly expressed as % oven volatiles. Most manufactured cigarette brands range from 12-18% moisture. The moisture content of tobacco that has been processed into a useful product has been altered numerous times. Each processing step, e.g., stem removal, cutting, blending components, adding flavors, expansion and fabricating into cigarettes, requires certain optimum moisture levels, which must be controlled carefully, to ensure top quality tobacco products. Moreover, the manner in which the moisture content of the tobacco is altered can have a lasting effect on the physical, chemical and subjective characteristics of the final product.
Filter Type	Carbon CA Other	Visual inspection	Charcoal filter tips selectively remove volatile ciliatoxic agents; cellulose acetate filters retain semi-volatile phenols and volatile nitrosamines; both types of filters can release fibers and other structural materials.
Filter Weight	g	5 cigarettes Analytical Balance	Directly related to smoke removal.
Rod Density	mg/cc	Calculated	Calculated from observed tobacco weight, rod length, and diameter. Gives an estimate of average cigarette packing density. This relates to ease of draw and pressure drop.
Filter Density	mg/cc	Calculated	Calculated from observed filter weight, length, and diameter. Associated with particle removal efficiency (filter efficiency)—a denser filter should trap more particles.

Smoke Emissions. Cigarettes were tested by Labstat International (Kitchener, ON, Canada) for tar, nicotine, and carbon monoxide using both the ISO and Canadian Intensive methods (described below, Table 3). Tar, nicotine, carbon monoxide, and puff count per cigarette are reported. Emissions testing was completed in January 2008.

Smoke Chemistries			(NOTE—For this report, Tar, nicotine, and CO values were obtained from an outside testing laboratory)
Tar	mg	ISO Canadian Intense	Total particulate matter minus water and nicotine; traditional but crude indicator of carcinogenic potential. Tar needs to be measured to relate to previous studies. Cigarettes are generally described by their tar yields. The concentration of tar in a cigarette determines its rating: High-tar cigarettes contain at least 22 milligrams (mg) of tar; Medium-tar cigarettes from 15 mg to 21 mg; Low-tar cigarettes 7 mg or less of tar.
Nicotine	mg	ISO Canadian Intense	Major addictive substance in tobacco. Not a carcinogen. Possible contributor to cardiovascular effects of smoking.
Carbon Monoxide	mg	ISO Canadian Intense	Odorless, poisonous gas. Product of incomplete combustion. Competes with oxygen for binding to hemoglobin in bloodstream. Hazardous to cardiovascular system.

Parameter	**ISO**	**Canadian Intense** (Recommended by WHO TobReg)
Puff Volume	35 ml	55 ml
Puff Interval	60 seconds	30 seconds
Puff Duration	2 seconds	2 seconds
Ventilation Holes	not blocked	fully blocked

Statistical Analyses

Data for individually measured cigarettes were aggregated for each measured parameter, and are reported as average values by brand. All statistical analyses were performed using SPSS 14.0 (SPSS Inc., Chicago, IL). Initial analyses comparing brands within country used descriptive statistics. Between country comparisons were performed using unpaired t-tests. Modeling of ISO and Canadian Intense emissions was performed using stepwise linear regression.

Results

Mean values for all parameters by brand tested are shown in Appendix A.

New Zealand cigarettes compared to those in other countries tested

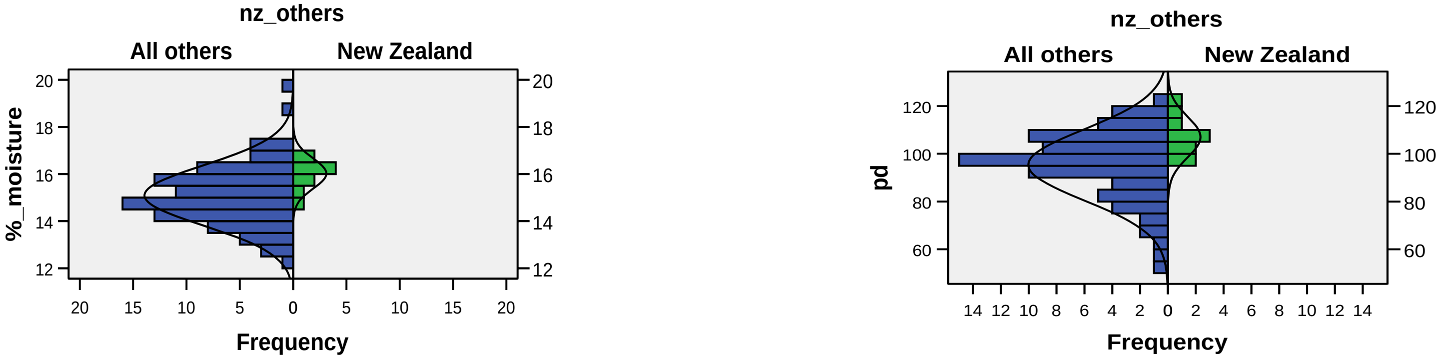
Our primary analysis was to compare the characteristics of New Zealand cigarettes to the characteristics of brands purchased in seven other countries (Turkey, Romania, India, Nepal, Indonesia, Mexico, Cyprus) and tested at the same time. All of the New Zealand cigarettes were filtered. However, Horizon King Size had no filter ventilation. Marlboro Lights had 4 rows of ventilation holes and all other varieties had bands of tiny perforations in the tipping paper.

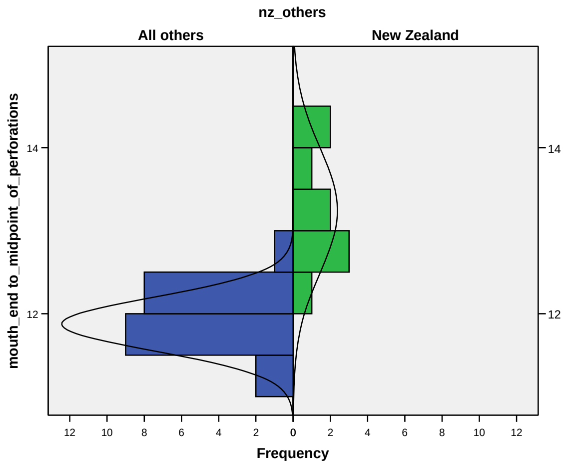
Of the 21 parameters tested, 3 showed statistically significant differences between New Zealand and other countries. Table 1 shows the mean differences. Figure 1 shows where New Zealand brands fit in the distribution of each parameter.

Table 1. Mean differences between New Zealand cigarettes and those in other countries on physical and design parameters.

Parameter	**New Zealand**	**Others**	**t-value**	**df**	**p-value**
Mouth_endto_midpoint_of_perforations	13.2	11.88	6.94	27	<.001
% Moisture	16.1	15.1	2.64	97	.010
Pressure Drop	107.1	95.19	2.61	82	.011

Figure 1. Distributions of values on physical and design parameters of interest, New Zealand vs. Other tested countries.

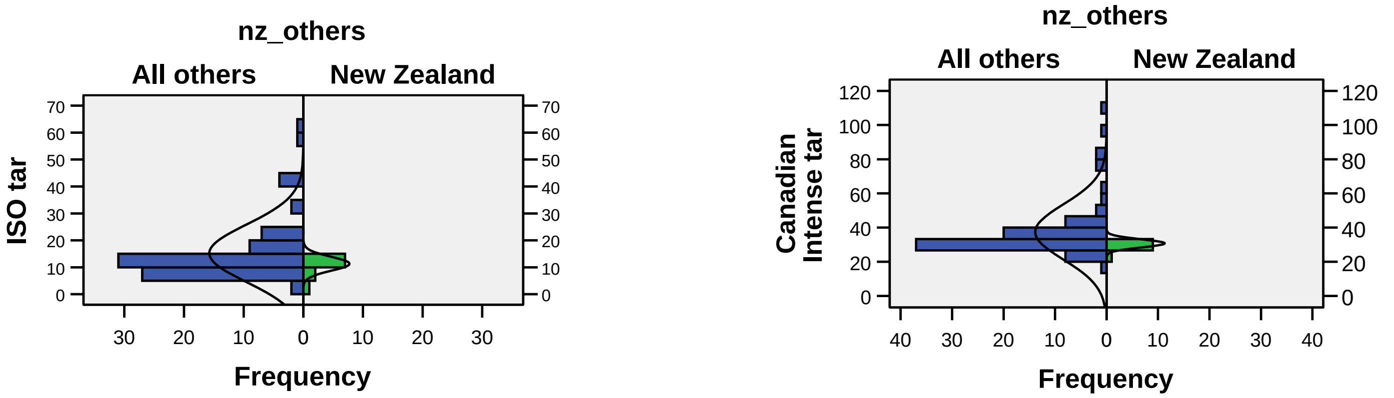




Emissions levels between countries

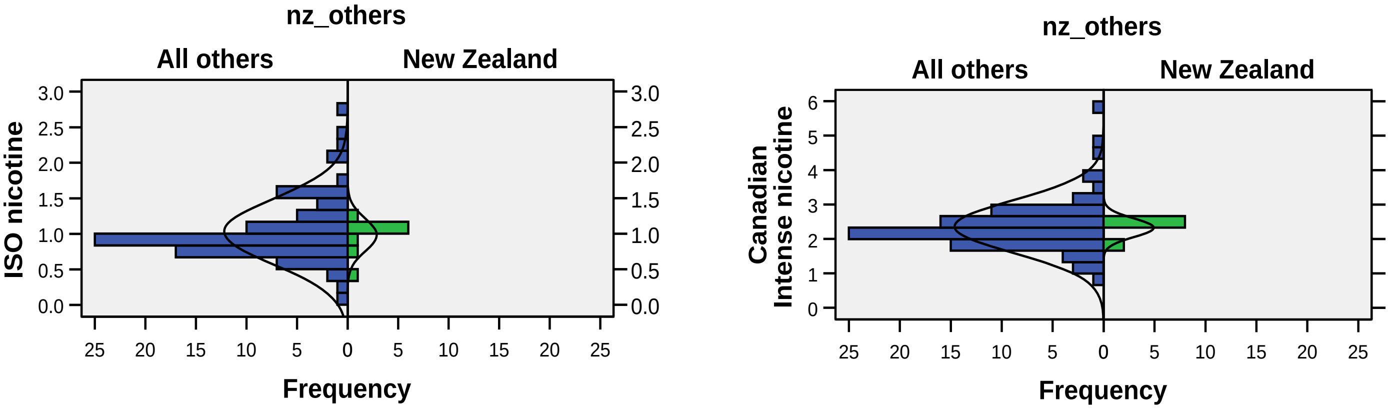
The New Zealand brands tested averaged a slightly lower ISO tar value than those measured in the other countries, though this was not statistically significant (11.12 vs. 15.27, p = 0.205). A similar difference was seen for the Canadian Intense tar value (30.60 vs. 37.56, p=0.160). Figure 2 shows the distributions of tar emissions for New Zealand versus Other tested countries.

Figure 2. Distributions of values of tar emissions levels under the ISO and Canadian Intense regimens, New Zealand vs. Other tested countries.



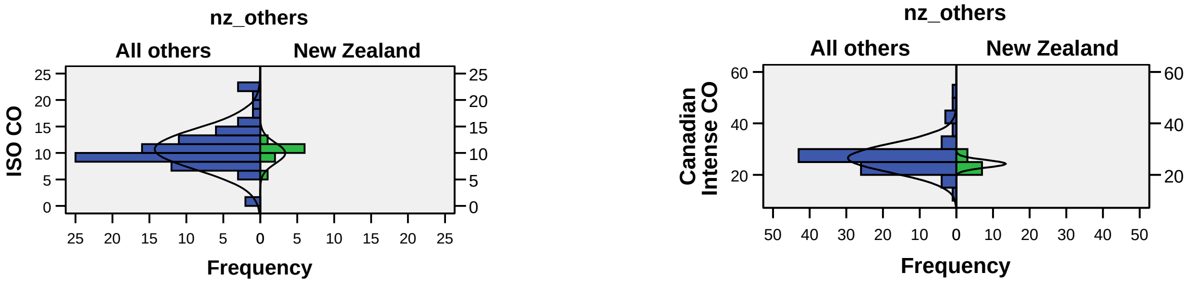
Nicotine yields for New Zealand brands showed no significant difference under ISO (0.98 vs. 1.03, p=.70) or Canadian Intense (2.33 vs. 2.37, p=.88) conditions. Figure 3 shows the distributions of nicotine emissions for New Zealand versus Other tested countries.

Figure 3. Distributions of values of nicotine emissions levels under the ISO and Canadian regimens, New Zealand vs. Other tested countries.



Similarly, New Zealand brands showed no difference in CO under the ISO regimen (9.76 vs 10.76, p=.409) nor the Canadian Intense regimen (24.26 vs. 26.56, p = 0.188). Figure 4 shows the distributions of CO emissions for New Zealand versus Other tested countries.

Figure 4. Distributions of values of CO emissions levels under the ISO and Canadian regimens, New Zealand vs. Other tested countries.



Relationship between physical and design features and emissions performance

We next examined how physical and design features related to tar emissions under both the ISO and Canadian regimens. An initial correlation matrix was produced for all pooled data to examine univariate correlations between physical and design features and emissions data. Separate regression models were then run for New Zealand versus Other tested sites.

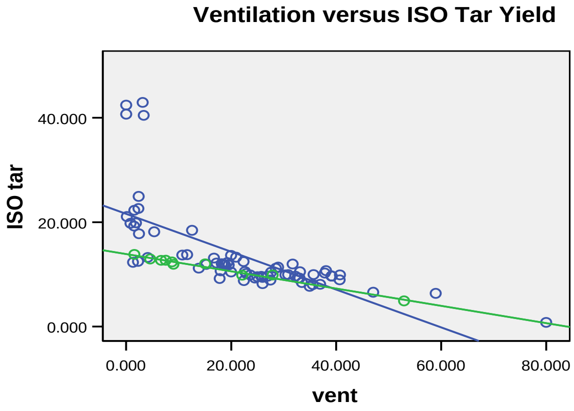
<u>Predictors of tar yield</u>. An overall correlational analysis showed that rod diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, paper porosity, and tobacco density all had significant univariate associations with tar yields. These variables were then used in a stepwise regression to identify the independent associations. Table 2 shows the parameters that predict tar yield in New Zealand brands versus Other countries tested.

Table 2. Predictors of tar yield for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 = 0.97$*		*$R^2 = 0.88$*	
Ventilation	-0.99	<.001	-0.36	<.001
Dry weight			0.65	<.001
Tipping paper length			-0.17	.003
Vacuum porosity			-0.10	.030
Canadian Regimen	*$R^2 = 0.86$*		*$R^2 = 0.85$*	
Ventilation	-0.93	<.001		
Dry weight			0.84	<.001
Tipping paper length			-0.22	<.001
Vacuum porosity			-0.11	.035

Analysis revealed that the primary predictor of tar yields under either ISO or Canadian Intense conditions for New Zealand cigarettes was filter ventilation. In other countries, other factors such as dry weight, tipping paper length, paper and vacuum porosity were significant contributors to variance in yields, though ventilation was dominant.

Figure 5. The univariate relationship between ISO tar yields and ventilation level for New Zealand versus the Other tested countries.



The chart above (Figure 5) shows the univariate relationship between ISO tar yields and ventilation level for New Zealand (green markers) versus the other tested countries (blue markers). One notes that there is a stronger relationship between ventilation and ISO yields in New Zealand compared to other countries.

Predictors of nicotine yield. An overall correlational analysis showed that rod diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, paper porosity, and tobacco density all had significant univariate associations with nicotine yields. These variables were then used in a stepwise regression to identify the independent associations. Table 3 shows the parameters that predict nicotine yield in New Zealand brands versus Other countries tested.

Table 3. Predictors of nicotine yield for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 = 0.77$*		*$R^2 = 0.78$*	
Ventilation	-0.89	<.001	-0.48	<.001
Dry weight			0.48	<.001
Tipping paper length			-0.16	.030
Rod diameter			-0.15	.018
Canadian Regimen	*$R^2 = 0.59$*		*$R^2 = 0.58$*	
Ventilation			-0.30	.002
Dry weight			0.58	<.001
Rod diameter			-0.21	.015
Filter weight	-0.80	.003		

Analysis revealed that for New Zealand brands, ventilation was the key predictor of ISO nicotine yield. For other countries, in addition to ventilation, dry weight, tipping paper length, and rod diameter all contributed significantly. Under the Canadian testing regimen, filter weight was the only predictor of nicotine yield for New Zealand brands, while dry weight, rod diameter and ventilation were predictors for other countries. The relatively low R-square value for other brands and New Zealand suggests unmeasured parameters may be playing a significant role.

Predictors of CO yield. An overall correlational analysis showed that rod diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, paper porosity, and tobacco density all had significant univariate associations with CO yields. These variables were then used in a stepwise regression to identify the independent associations. Table 4 shows the parameters that predict CO yield in New Zealand brands versus Other countries tested.

Table 4. Predictors of CO yield for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 =0.95$*		*$R^2 = 0.92$*	

Ventilation	-1.07	<.001	-0.64	<.001
Dry weight			0.54	<.001
Vacuum porosity			-0.13	.001
Rod Diameter	0.27	.008		
% Moisture			0.13	.006
Filter density			-0.12	.037
Canadian Regimen	*$R^2 = 0.59$*		*$R^2 = 0.86$*	
Dry weight			0.95	<.001
Rod diameter	0.79	.004	0.13	.014
Vacuum porosity			-0.14	.009
% moisture			0.16	.005
Filter length			0.13	.016

For New Zealand brands tested under the ISO regimen, ventilation and rod diameter were the key factors in determining CO yields. For brands in other countries, dry weight, vacuum porosity, moisture, and filter density contributed variance independent of ventilation. Under the Canadian regimen, rod diameter was the key factor in determining CO yields while dry weight was the primary determinant in other countries, with rod diameter, vacuum porosity, moisture and filter length explaining significant variance. The relatively low R-square value for New Zealand suggests unmeasured parameters may be playing a significant role.

Predictors of puff counts. The number of puffs taken in a standard test is an important determinant of yields, so factors that affect puff count can contribute indirectly to yield numbers. An overall correlational analysis showed that rod diameter, tobacco length, dry weight, % moisture, ventilation, paper porosity, tobacco density, and filter density all had significant univariate associations with puff count. These variables were then used in a stepwise regression to identify the independent associations. Table 5 shows the parameters that predict puff counts in New Zealand brands versus Other countries tested.

Table 5. Predictors of puff counts for New Zealand brands versus Other countries tested.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 = 0.32$*		*$R^2 = 0.92$*	
Dry weight			0.99	<.001
% moisture	0.62	.042	0.09	.024
Canadian Regimen	*$R^2 = 0.65$*		*$R^2 = 0.93$*	

Dry Weight			0.96	<.001
Tobacco length	0.83	.002		

Dry weight and moisture content emerged as significantly associated with puff counts for other brands tested, but moisture was found to be significant for New Zealand brands tested under the ISO Regimen. Under the Canadian Intense regimen, tobacco length was the significant independent predictor of puff count for New Zealand cigarettes, while for Others, only dry weight, was significantly associated.

<u>Predictors of tar yield per puff</u>. Correcting tar yields for the total number of puffs can provide insight into how various physical and design components are contributing to particulate generation. An overall correlational analysis showed that filter diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, tobacco density, filter density, and paper porosity all had significant univariate associations with tar per puff. These variables were then used in a stepwise regression to identify the independent associations. Table 6 shows the parameters that predict yar yield per puff in New Zealand brands versus Other countries tested.

Table 6. Predictors of tar yield per puff for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 = 0.95$*		*$R^2 = 0.88$*	
Ventilation	-0.98	<.001	-0.59	<.001
Dry weight			0.25	<.001
Tipping paper length			-0.22	<.001
Filter density			-0.24	<.001
Canadian Regimen	*$R^2 = 0.52$*		*$R^2 = 0.38$*	
% Moisture	-0.75	.007		
Ventilation			-0.24	.041
Filter weight			-0.30	.017
Vacuum porosity			-0.31	.005
Tipping paper length			-0.27	.034

This analysis provided interesting yet complex results. For New Zealand brands, ventilation was the dominant predictor of tar per puff. The picture is more complex in the remaining brands tested. Ventilation was again the first variable entered and accounted for significant variance, but weight, tipping paper length, and filter density all contributed independently to predicting tar per puff. This is suggestive of a greater diversity in design in the other cigarettes relative to a more homogenous New Zealand set. The analysis simplified somewhat when Canadian Intensive data were considered. For New Zealand brands, moisture was the key driver of tar/puff under CI conditions, while for the Other brands, ventilation, filter weight, tipping paper length and vacuum porosity all had significant contributions. Though, the relatively low R-square value for other brands suggests unmeasured parameters may be playing a significant role.

Predictors of nicotine yield per puff. Correcting nicotine yields for the total number of puffs can provide insight into how various physical and design components are contributing to particulate generation. An overall correlational analysis showed that filter diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, tobacco density, filter density, and paper porosity all had significant univariate associations with tar per puff. These variables were then used in a stepwise regression to identify the independent associations. Table 7 shows the parameters that predict nicotine yield per puff in New Zealand brands versus Other countries tested.

Table 7. Predictors of nicotine yield per puff for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	$R^2 = 0.81$		$R^2 = 0.74$	
Ventilation	-0.91	<.001	-0.69	<.001
Filter diameter			-0.17	.011
Filter density			-0.32	<.001
Canadian Regimen	$R^2 = 0.42$		$R^2 = 0.28$	
Filter density	-0.69	.018	-0.45	<.001
Filter diameter			-0.35	.003

Results for nicotine per puff were somewhat less complex than for tar. For New Zealand brands, ventilation was the key parameter under the ISO regimen, while for other countries, ventilation, filter diameter, and filter density were important. Under the Canadian regimen, a different pattern was seen. For New Zealand brands, the key determinant was filter density, while for other brands it was the density and diameter of the filter. Under the Canadian regimen, R-square values for both locations are noticeably lower, suggesting unmeasured parameters may have significant influence on nicotine per puff.

Predictors of CO yield per puff. Correcting CO yields for the total number of puffs can provide insight into how various physical and design components are contributing to particulate generation. An overall correlational analysis showed that filter diameter, tipping paper length, tobacco length, filter length, dry weight, % moisture, ventilation, tobacco density, filter density, and paper porosity all had significant univariate associations with CO per puff. These variables were then used in a stepwise regression to identify the independent associations. Table 8 shows the parameters that predict CO yield per puff in New Zealand brands versus Other countries tested.

Table 8. Predictors of CO yield per puff for New Zealand brands versus Other tested countries.

Parameter	**New Zealand**		**Others**	
	Beta	**p**	**Beta**	**p**
ISO Regimen	*$R^2 = 0.91$*		*$R^2 = 0.89$*	
Ventilation	-0.92	<.001	-0.91	<.001
Dry Weight			-0.28	<.001
Filter density			-0.19	.004
% Moisture			0.11	.049
Vacuum porosity				
Filter diameter	0.29	.016		
Canadian Regimen	*$R^2 = 0.97$*		*$R^2 = 0.54$*	
Tobacco length	-0.75	<.001		
Wet rod density	-0.38	.001		
% Moisture	-0.15	.033		
Dry weight			-0.58	<.001
Ventilation			0.33	.001
Vacuum Porosity			-0.21	.020

Assessment of CO per puff showed an interesting pattern of results which differed by location. For New Zealand, ventilation was the key determinant under ISO conditions, with filter diameter contributing significant unique variance. For other tested countries, in addition to ventilation, dry weight, filter density and moisture all explained variation in the outcome. Under Canadian conditions, CO/puff was related to tobacco length, wet rod density and moisture in New Zealand. For other countries, dry weight, vacuum porosity, and ventilation were signifcantly related to CO/puff.

Discussion

In our assessment of cigarettes from New Zealand, it became clear that ventilation was the key parameter distinguishing these products from those tested in other countries. Average filter ventilation across the New Zealand tested brands were at a slightly higher level than those seen across brands tested in seven other countries. Ventilation was the key (and sometimes the only) predictor of tar, nicotine, and CO yields of New Zealand cigarettes under the ISO regimen, lending further confirmation to the close relationship between filter ventilation and ISO test performance. When brands were tested under the Canadian Intensive regimen, which blocks filter vents, levels were higher, and variability across brands was expanded. Nevertheless, ventilation was a key predictor of tar and nicotine (but not CO emissions) for New Zealand brands under Canadian Intense conditions—since vents are block, they should theoretically have no influence, so ventilation may actually in this context be serving as a proxy for other unmeasured parameters (such as % of expanded tobacco) that are correlated with filter ventilation.

The key predictor for number of puffs taken in the ISO test among tested New Zealand brands was moisture. For the other tested countries, dry weight and moisture were significant predictors. For the Canadian Intense regimen, tobacco length was the key predictor for number of puffs taken for New Zealand and dry weight was the primary predictor for other brands. Since puff count in standard testing is an important performance consideration for the industry, it and its design correlates should be of interest to tobacco control researchers.

In examining design correlates of tar, nicotine, and CO yields per puff, interesting patterns of results were seen that differed in several aspects from those of per-cigarette TNCO yields. New Zealand brands had yields per puff that largely could be attributed to ventilation, length of tobacco, filter density, and moisture while brands tested from other markets had a much greater diversity of design predictors. The more homogenous mix of New Zealand products, combined with the large effect of ventilation on reducing yields, overall, is the most likely explanation for this difference.

Conclusions

- New Zealand brands had a slightly higher level of filter ventilation as brands tested in other countries
- Ventilation was the key predictor of ISO tar, nicotine, and CO yields
- Tar and nicotine yields were higher under Canadian Intensive conditions
- Per-puff tar, nicotine, and CO yields were influenced by parameters such as % moisture, filter density and tobacco length, suggesting these parameters are important for regulators to consider

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Further Reading

Baker RR. The Development and Significance of Standards for Smoking-Machine Methodology. Beitrage zur Tabakforschung International/Contributions to Tobacco Research 2002; 20:23-41.

Bialous SA, Yach D. Whose standard is it, anyway? How the tobacco industry determines the International Organization for Standardization (ISO) standards for tobacco and tobacco products. Tob Control 2001; 10:96-104.

Bradford JA, Harlan WR, Hanmer HR. Nature of cigarette smoke. Technique of experimental smoking. Industrial and Engineering Chemistry 1936; 28:836-839.

Burns DM, Majors J, Shanks TG, Thun MJ. Smoking Lower Yield Cigarettes and Disease Risks. Bethesda: National Institutes of Health; 2001.

Counts ME, Morton MJ, Laffoon SW, Cox RH, Lipowicz PJ. Smoke composition and predicting relationships for international commercial cigarettes smoked with three machine-smoking conditions. Regulatory Toxicology and Pharmacology 2005; 41:185-227.

Hammond D, Fong GT, Cummings KM, Hyland A. Smoking topography, brand switching, and nicotine delivery: results from an in vivo study. Cancer Epidemiol Biomarkers Prev 2005; 14:1370-1375.

Hoffmann D, Hoffmann I. The Changing Cigarette, 1950-1995. Journal of Toxicology and Environmental Health 1997; 50:307-364.

Jarvis MJ, Boreham R, Primatesta P, Feyerabend C, Bryant A. Nicotine yield from machine-smoked cigarettes and nicotine intakes in smokers: evidence from a representative population survey. J Natl Cancer Inst 2001; 93:134-138.

Kozlowski LT, Goldberg ME, Yost BA, Ahern FM, Aronson KR, Sweeney CT. Smokers are unaware of the filter vents now on most cigarettes: results of a national survey. Tob Control 1996; 5:265-270.

Kozlowski LT, Mehta NY, Sweeney CT et al. Filter ventilation and nicotine content of tobacco in cigarettes from Canada, the United Kingdom, and the United States. Tob Control 1998; 7:369-375.

Kozlowski LT, O'Connor RJ, Sweeney CT. Cigarette Design. Risks Associated with Smoking Cigarettes with Low Machine-Measured Yields of Tar and Nicotine 2001;13-38.

Kozlowski LT, O'Connor RJ. Cigarette filter ventilation is a defective design because of misleading taste, bigger puffs, and blocked vents. Tob Control 2002; 11 Suppl 1:140-150.

O'Connor RJ, Cummings KM, Giovino GA, McNeill A, Kozlowski LT. How did UK cigarette makers reduce tar to 10 mg or less? BMJ 2006; 332:302.

Appendices

A. Excel file of New Zealand cigarette data.