

Evaluation of an Electrically Heated Cigarette

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Introduction

In the conventional cigarette, the tobacco serves both as a heat source and as a source for taste. Because of this, on a per unit weight of total particulate matter (TPM) basis, the cigarette smoke composition and its measured biological activity do not differ greatly between classic unfiltered cigarettes and new ultra light American-blend cigarettes, which deliver between 40 and 1 mg tar. Decoupling the energy source from the source of taste creates new possibilities for changing product attributes. Here we present data on the chemical composition of smoke from an electrically heated cigarette prototype with controlled combustion (EHC) and on the biological activity of the smoke.

Principle of Operation

- An EHC prototype containing tobacco filler wrapped in tobacco mat (the amount of tobacco used being approximately 50% of that used in a conventional cigarette) is kept in constant contact with 8 electrical heater blades in a microprocessor-controlled lighter.
- This novel cigarette is equipped with a combined cellulose acetate/charcoal filter.
- One of the 8 blades is triggered by each puff and an unshed section of the cigarette is heated for a defined duration at a defined energy level.
- The electrical heating causes the tobacco under the heater blade to burn at a low temperature during each puff.
- The amount and composition (e.g., ratio of distilled vs pyrolyzed compounds) of the resulting smoke, as well as the taste, depend on the cigarette design and the amount of energy applied.

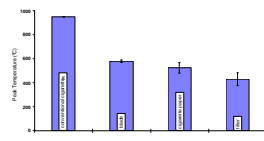
EHC Cigarette with Electric Lighter



explosion view showing cigarette construction consumed cigarette showing burn marks cigarette in lighter, ready for use

Operating Conditions

heating duration: 2 s/puff
total heating energy: 23 J/puff
number of puffs: 8 puffs/cigarette

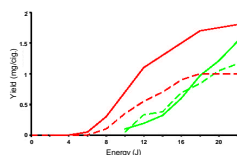


Dependency of Yields on Energy

The yield of distilled and pyrolyzed smoke components depends on the energy applied. For typical EHC prototypes, each of these classes shows a different energy dependency:

- Distillation (e.g., of glycerol, nicotine) starts at a lower energy level than pyrolysis (e.g., generation of water, CO).
- Distillation approaches a steady state at high energy levels.
- Pyrolysis progresses with increasing energy.

Absolute Yield of typical EHC prototypes



— glycerol (mg/cig. x 5)
— nicotine (mg/cig. x 5)
— carbon monoxide (mg/cig.)
— water (mg/cig.)

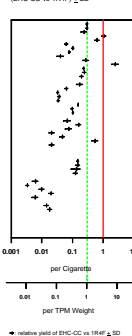
Smoke Composition

The low temperature pyrolysis of tobacco in EHC prototypes causes distinct shifts in the composition of the smoke compared to conventional cigarettes:

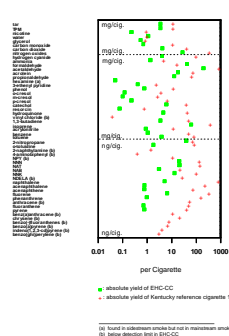
A recent cigarette prototype with a cellulose acetate/charcoal filter (EHC-CC) is characterized — on a per TPM weight basis — by

- an increase in yields of distillation products (e.g., glycerol),
- an increase in yields of some low temperature degradation products (e.g., H₂O, formaldehyde),
- a decrease in yields of incomplete combustion products (e.g., CO, NO, PAHs),
- a decrease in yields of pyrolysis products (e.g., nitrosamines).

Relative Yield (EHC-CC vs 1R4F) ± SD



Absolute Yield



Bacterial Mutagenicity of Various EHC Prototypes

The Salmonella reverse mutation assay (Maron and Ames, 1983) was optimized for strains TA98, 100, 1535, and 1537 for the evaluation of cigarette smoke condensate to allow discrimination between cigarette prototypes that differ in mutagenic activity.

- The mutagenicity of TPM in smoke from the EHC-CC prototype is distinctly lower than that of the 1R4F cigarette.
- This holds true for all OECD-requested tester strains with and without metabolic activation.
- This is consistent for all EHC prototypes.

In Vitro Cytotoxicity of Various EHC Prototypes

The neutral red uptake assay (INVITTOX, 1990) on mice embryo BALB/c 3T3 cells (ATCC CCL 163) was optimized for the evaluation of cigarette smoke — TPM and the water-soluble fraction of the gas/vapor phase (GVP) trapped in phosphate buffered saline — to allow discrimination between cigarette prototypes that differ in cytotoxic activity.

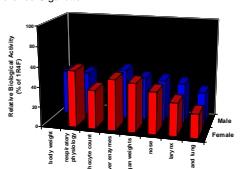
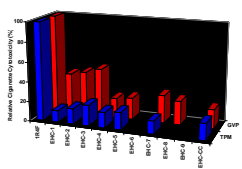
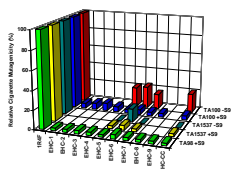
- The cytotoxicity of the smoke from the EHC-CC prototype is distinctly lower than that of the 1R4F cigarette.
- This holds true for both the TPM and the GVP.
- This is consistent for all EHC prototypes.

Subchronic Inhalation Toxicity of the EHC-CC Prototype

The subchronic inhalation study (in accordance with OECD 413,1981) on male and female Sprague-Dawley rats was optimized for the evaluation of the irritancy of diluted cigarette smoke. Inhalation of smoke from the EHC-CC prototype well above the minimal toxic dose resulted in

- histological changes (indicative of irritancy) in the mucosa of the upper and lower respiratory tract (i.e., hyperplasia, squamous metaplasia, ciliary cell atrophy, epithelial thickening, goblet cell hyperplasia, pigmented alveolar macrophages),
- hematological changes (i.e., lymphocyte count),
- biochemical changes (i.e., increased serum activity of alanine aminotransferase, aspartate aminotransferase and alkaline phosphatase),
- body and organ weight changes (i.e., increases in relative weight of lungs and adrenals, and decreases in relative weight of spleen).

All these changes are typically observed following subchronic inhalation of smoke from conventional cigarettes. Compared on a per cigarette basis, the concentration ratios for equal effects indicate that the biological activity of smoke from the EHC-CC prototype is approximately 60% lower than that of the Reference Cigarette 1R4F.



Conclusion

The concept of the electrically heated cigarette — decoupling the energy source from the source of taste — allows the cigarette to reach a lower peak temperature when burned than a conventional cigarette and at the same time use less tobacco. This results in lower yields of most biologically active smoke components and in a lower biological activity of the smoke compared on a per cigarette basis.

References

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- Partic: Organization for Economic Co-operation and Development, 1981

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