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Tobacco smoke: Unraveling a controversial subject ☆, ☆☆

Anja Thielen[a,1], Hubert Klus[b], Lutz Müller[c,*]

[a]*Tabak und Rauchen GmbH, Neustädtische Kirchstraße 8, 10117 Berlin, Germany*
[b]*Oriongasse 9, 3100 St. Pölten-Wagram, Austria*
[c]*Stralsunder Straße 1, 01109 Dresden, Germany*

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Dedicated to Dr. Richard R. Baker

Abstract

Cigarettes are a modern and industrial form of tobacco use and obviously involve more than just tobacco. A multitude of physical processes and chemical reactions occur inside the burning zone of a cigarette. Cigarette smoke is an aerosol of liquid droplets (the particulate phase) suspended within a mixture of gases and semi-volatile compounds. Two kinds of smoke with different composition and properties are produced during smoking: mainstream smoke inhaled by the smoker and sidestream smoke, which is released into the environment between puffs from the lit end of the cigarette.

Several techniques and modifications have altered the design of the cigarette during the last 50 years and changed smoke composition, with the effect of lower tar and nicotine smoke yields. An enormous amount of research has been done since the 1950s on smoke composition. With regard to the numerous toxic or carcinogenic constituents identified in tobacco smoke, there is a strong focus in the industry and with the authorities on the over 40 compounds, called ''Hoffmann analytes''.

The yields of tar and nicotine in mainstream smoke of a cigarette brand as printed on the pack are measured with smoking machines under highly standardized conditions. Yields must comply with regulatory limits set in a number of countries. Smoking by machine is different from the smoking behavior of humans. There is a growing movement to develop more ''realistic'' methods to estimate smoke yields. But it is unclear whether alternative smoking regimens are more representative of human smoking behavior and provide better predictions of human exposure.

Tobacco smoke has strong biological and toxicological effects *in vitro* and *in vivo*. There is an obvious need for developing a unified and validated testing approach particularly for the assessment of additives and the evaluation of new potentially reduced exposure products (PREPs).

This paper gives a comprehensive overview of cigarette design, the composition and toxicity testing of smoke, and the way machines and people smoke – with links to the more detailed literature.

Keywords: Cigarette design; Cigarette smoke constituents; Hoffmann analytes; Machine smoking; Smoking behavior; Toxicity testing

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☆☆Dr. Richard R. Baker was originally invited to be the speaker on tobacco smoke. He worked on his talk until his unexpected death at Easter 2007. Using the material he had prepared, friends of his finished the presentation and one of them (L.M.) gave it at the conference. This paper is dedicated to an excellent scientist and a very good friend.

*Corresponding author. Tel.: +49 351 890 2922; mobile: +49 151 152 15203.
E-mail address: Lutz.Mueller.DD@t-online.de (L. Müller).
[1]Present address: Karl-Stieler-Straße 12a, 12167 Berlin, Germany.

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Introduction

In 1492, Christopher Columbus returned to Europe from what was to be called America with the first tobacco leaves and seeds ever seen in the Old World. Initially, European doctors recommended tobacco as a cure for toothache, worms and other ailments. Queen Catherine de Medici used tobacco to treat her migraines after the French ambassador in Portugal, Jean Nicot, had acquired tobacco seeds in Lisbon and introduced the tobacco plant to France in 1561. In his honor, the Swedish botanist Carolus Linnaeus named the tobacco plant genus *Nicotiana* in 1753.

In the 18th century, snuff and pipe smoking were the most popular forms of tobacco use. The 19th century became the age of the cigar. Cigarettes were largely unknown in the English-speaking world before the Crimean War when British soldiers began emulating their Ottoman Turkish comrades, who had the habit of rolling tobacco in newsprint paper. The invention of machines for the manufacturing of cigarettes in the 1850s opened the way for mass production and the development of the modern forms of cigarettes in the 20th century.

Cigarette consumption has since been rising steadily to reach a worldwide consumption of nearly 5.6×10^{12} cigarettes in 2000 (American Cancer Society, 2006). Tobacco use has always been a controversial issue with its increasing popularity on the one side and the growing evidence of health risks on the other. An enormous amount of research has since been done on this subject and there are still open questions, which call for additional research. Today, the regulation of tobacco products and their use, and the need for tobacco products with reduced risk are in the focus of the activities of authorities and the industry.

What follows is a comprehensive overview of the design of cigarettes, the composition of smoke, approaches to toxicological testing and the way standardized analytical machines and real people smoke. A number of references are included for further reading.

The modern cigarette

Commercially manufactured cigarettes consist of a tobacco blend, paper and usually, but not always, a filter.

Mainly three types of tobacco are used for the manufacturing of cigarettes worldwide: Virginia, Burley and Oriental (Table 1). The distinct tobacco types, and the methods how the leaves are cured after harvest, lead to characteristic flavor profiles and composition of smoke of the finished product. Curing of leaves is the carefully controlled process used to develop the texture, color and overall quality of a specific tobacco type. During curing, many chemical and physical changes take place in the tobacco leaf. For instance, starch is converted into sugar, the green color vanishes and the tobacco changes its color from light yellow to orange and brown as tree leaves do in fall.

Table 1. General characteristics of the three important tobacco types after curing

	Virginia/Bright	Burley	Oriental
Leaves	Large, orange	Large, brown	Small, orange
Nicotine	Middle to high	High	Low
Sugar	High	None	High
Curing	Flue-curing	Air-curing	Sun-curing

The Virginia tobacco type is named after the US state where it was first grown. The large leaves generally contain a relatively high amount of nicotine. The flue-curing process is fast (5–7 days) and conserves the natural high amount of sugar. Flue-curing is the process when heat is introduced into a barn with the leaves – indirectly by means of a pipe system or, in former times, directly as exhaust gases of an external furnace. Because of its yellow/orange color after flue-curing, Virginia is also called Bright tobacco.

Growing Burley tobacco requires heavier soils and more fertilizer than Virginia. After being air-cured in unheated, ventilated barns to dry naturally for a period of about 7 weeks, the tobacco turns brown with virtually no sugar left, giving its smoke a harsh taste.

Oriental is a tobacco type with rather small leaves. Oriental is densely planted and grown in the hot summer of the Balkans, Greece, Turkey and the Middle East. These growing conditions help create its intensely aromatic flavor and a high sugar content, which are subsequently enhanced by sun-curing. Sun-cured tobacco leaf is strung out on racks and exposed to the sun.

Another type of air-cured tobacco is Maryland tobacco, which is typically used in small amounts in cigarettes manufactured in the United States.

The primary component of a cigarette, of course, is tobacco but today's cigarettes involve much more than just tobacco (Fig. 1). Cigarettes are a modern and industrial form of tobacco use with a rather complex design providing the consumer with a product of high and consistent quality.

For the better appreciation of what follows, it is useful to keep two definitions in mind. ''Ingredient means any substance or any component except for tobacco … used in the manufacture or preparation of a tobacco product …, including paper, filter, inks and adhesives'' (The European Parliament and the Council of the European Union. Directive 2001/37/EC). Additives are generally understood to be substances added to