METHOD ARTICLE

The manufacture of filtered cannabis cigarettes: uniform particle distribution and combustion properties for consistent cannabinoid delivery [version 1; referees: awaiting peer review]

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Abstract

Here we describe a manufacturing process for the production of commercial filtered Cranfords cannabis cigarettes (CN). Unlike production of filtered tobacco cigarettes, standardization in the manufacture of cannabinoid containing cigarettes is lacking. The numerous cannabis strains with variable cannabinoid content, differences in cultivation methods and variability in assembly associated with hand-rolled cannabis cigarettes makes consistent cannabinoid inhalation dosing challenging. To address the growing need for standardization in the manufacture of cannabis cigarettes we developed a process for the production of filtered CN using machine-rolled tobacco cigarette equipment. The processed CN packing density, particle size distribution and curing procedures were designed to produce filtered CN that were identical in appearance and qualitatively similar in combustion properties to market-leading filtered commercial tobacco cigarettes. Quality control procedures were implemented to assure consistency in the manufacturing process and minimize variability associated with cigarette production such as inconsistencies in packing density, particle size, and combustion rate of mainstream smoke. Passive inverted smoldering assessment indicated that CN cigarettes burned at a faster rate compared to commercial filtered tobacco cigarettes of similar density. Overall, it is expected that machine-rolled standardized cannabis cigarettes with control over filler particle sizes, packing density and smoldering rates will contribute to making inhalation dosing of cannabis cigarettes more effective for therapeutic use.

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Introduction

Cannabis-based preparations have been used for the treatment of a variety of medical conditions. Although there are dozens of molecular variants of cannabinoids in a typical cannabis plant, the main psychoactive component of cannabis is Δ9 tetrahydrocannabinol (THC) converted from the decarboxylation of the biosynthetic precursor tetrahydrocannabinolic acid (THCA) during combustion. In 1997, the NIH reviewed scientific data concerning potential therapeutic uses for marijuana and hemp and found there may be beneficial medicinal effects and recommended that researchers develop alternative dosage forms (NIDA, 1997). Since then, at least four clinical trials have examined smoked cannabis compared with placebo for therapeutic uses (Abrams *et al.*, 2007; Ellis *et al.*, 2009; Ware *et al.*, 2010; Wilsey *et al.*, 2008). All four trials found a positive treatment effect with no serious adverse effects. Despite the wealth of data showing the medicinal effectiveness of cannabis and THC, the FDA has not approved the marijuana or hemp plant as medicine.

The most common route of THC administration is inhalation of smoke. The concentration of THC that may be inhaled from smoking a cigarette is determined by the THC content itself or the non psychoactive biosynthetic precursor THCA, which is present in the processed dried cannabis buds and small leaves. Each 700 mg CN cigarette contains less than 0.4% (~3 mg) THC and ~11% (77 mg) THCA by weight. More than 95% of the potentially active THC resulting from smoking is derived from THCA, which is converted to active THC by heat-induced decarboxylation at temperatures above 115°C during combustion (Dussy *et al.*, 2005). The direct relationship between temperature-dependent conversion of THCA to THC indicates that consistency in combustion across cigarettes is important for reliable THC dosing.

Once inhaled, the THC laden smoke is absorbed in the lungs within seconds and rapidly exerts its pharmacological activity via actions on the cannabinoid receptors located throughout the brain and body. Although several routes of administration exist, inhalation via smoking is the most common, least expensive and most effective route (Ohlsson *et al.*, 1980). Compared to oral administration, inhalation administers more rapid peak plasma levels and pharmacological effects. By comparison, oral administration produces variable peak plasma levels in humans between 60–90 minutes and pharmacological actions between 120–180 minutes after intake, while inhalation produces peak plasma levels in 3 minutes and pharmacological effects in 10 minutes (Ohlsson *et al.*, 1980). The rapid onset and dissipation of effects enables users to better self-titrate dosing. Unfortunately, it is difficult to determine the effective dosage of smoked cannabis, since the concentration of THC from smoking cannabis can be variable and subject to several factors related to the preparation including, growing conditions, the relative concentration of cannabinoids, the packing density of the material, the puff volume and frequency, the depth of inhalation into the lungs, additives that influence combustion and absorption of the cannabinoids in the lungs and temperature of the smoke.

The goal of this report is to describe a simple standardized procedure for the commercial production of machine-rolled filtered Cranfords cannabis cigarettes (CN) in a manner similar to commercial tobacco filtered cigarettes. To benefit from the therapeutic actions of inhaled THC it is important to produce a cigarette with consistent cannabinoid content and delivery. Improved THC dose consistency resulting from machine-rolling a filtered CN as an alternative to the variable unfiltered hand-rolled cannabis cigarettes is important because many of the therapeutic effects of inhaled THC arise within a narrow therapeutic low-dose window while at larger doses the psychoactive intoxicating actions can impair cognitive function, mood and judgment. The inclusion of a filter in the CN has advantages based on the utility of filters in tobacco cigarettes. For example, it provides a firm mouthpiece and permits the smoker to avoid direct contact with the cannabis. It can prevent particulates from entering the lungs and it reduces the temperature of the smoke entering the mouth. It is known that filters can selectively remove certain constituents of tobacco smoke, including phenols and alkylphenols (Baggett & Morie, 1973; Hoffmann & Wynder, 1963).

We describe a standardized method for the commercial production and manufacture of machine-rolled filtered CN with combustion properties similar to commercial tobacco cigarettes. Recent medicinal use legalization of cannabis cultivation, production and usage in Colorado and at least 23 other States has resulted in a growing industry that lacks coherence in cultivation and the type of regulatory oversight that exists in the pharmaceutical, food safety or tobacco industries. Establishing low-cost quality control tests is important, not only from a therapeutic THC dosing perspective, but also from a consumer protection perspective because contaminants like pesticides, herbicides, additives and toxins from fungi have been reported in processed cannabis (Llewellyn & O'Rear, 1977). It has been reported that few cannabis cultivation and processing operations follow industry best practices, largely because a historically illicit market led producers to compromise on plant health and contaminant safety in order to maximize yield instead of a safe, reliable product (Cohen & Ziskind, 2013). More reliable standardized cultivation and processing of cannabinoid delivery systems is important for both recreational and medicinal consumption. Tighter control and automation of the manufacturing process leading to a reliable commercial cigarette cannabinoid delivery device is a useful step towards this objective.

Methods

The production of CN filtered cigarettes from *Cannabis sativa L.* are described as follows:

1. Cannabis strains (Ghost train haze & Larry OG) of high THC (10–11% by weight) cannabis are organically grown without pesticides or added chemicals using nutrients/ingredients registered with OMRI (http://www.omri.org). OMRI offers independent review of brand name input products intended for organic farming and processing. OMRI's standards are based on the U.S. National Organic Program (NOP) and on the Canada Organic Regime (COR) standards. The plants are grown for ~120 days before hanging inverted under humidity and temperature controlled conditions (60% humidity, at 24°C for 11–13 days).

2. After removing stems and seeds the plant buds, trichomes and small leaves (<3 cm) are chopped into small particles. Process chopping is accomplished using a rotating food

processor blade for 5–7 minutes such that the final chopped material is between 0.04–10 mm in diameter before sifting with a 10 mm/10 mm opening/aperture stainless steel filter mesh screen.

3. The plant material is homogenized in a batch cement-style mixer containing ~11.3 kg of material rotating ~20 turns/minute for 60 minutes.

4. The plant material is humidified in a climate-controlled environment set at 60% humidity and 24°C under fan-mediated circulating air in 1 m × 0.6 m 0.6 m containers filled 75% full and rotated by inverting the storage container into an empty container every 12 hours for a period 2–3 days. The rotation is used to prevent the growth of fungi.

5. The RYO cigarette rolling machine (RYO Machines LLC, Girard, OH) is prepared by lightly hand spraying cannabis contact points with food grade oil-based lubricant (e.g. vegetable, soy, canola, hemp, corn, etc) before loading the cigarette tube blanks. Unlike tobacco processing machines lubricant is required to prevent adherence of cannabis resin to the machine parts.

6. To prevent plant material adhering to the pistons of the machine, the pistons that pack the plant material into the paper blanks are constructed of Teflon.

7. The cigarette rolling machines are loaded with blank paper tubes (8 mm diameter, 70 mm length and a 12 mm filter) containing a ~1 cm cellulose acetate or cotton based filter. Filter tubes are loaded and the plant material is then filled into the tubes using a custom-made (Cranfords LLC) filling spout at a pressure of ~80 PSI designed to fill the tubes completely with processed plant material.

8. The filling spouts are inserted into blank paper cigarette tubes to fill them with processed plant material.

9. Filled cigarettes are collected in a tray approximately 0.3 m long × 0.1 m wide × 0.1 m deep and stored at ~30% humidity at 24°C for 12 hrs before packaging.

Particle measurement in CN was determined by digital caliper measurements of individual randomly sampled cigarettes. Individual cigarettes containing 700 mg of material were emptied into a conical tube and shaken vigorously to separate the dried plant matter. A subsample was then emptied to a plate and 50 particles/cigarette were randomly selected and measured from a cross-sectional area of 0.04 to 90 mm^2.

Inverted passive smoldering was determined by hanging single CN, Camel Blue (CB) (RJR Winston-Salem, NC), or Newport (NP) (RJR Winston-Salem, NC) cigarettes (82 mm length × 8 mm diameter) by the filter region in an open Ball® 16 oz canning jar immediately after igniting the cigarette for a period of 10–11 seconds. The smoldering coal for each cigarette was allowed to burn to a demarcated point where 5 cm of the cigarette was converted to ash with ambient temperature between 22–26°C and relative humidity of 20% and the smoldering rate was measured using a digital stopwatch.

Results & discussion

Cigarette smoke from tobacco or cannabis is formed by the condensation of chemicals formed by the combustion of dried plant material, pyrolysis and pyrosynthesis, and aerosolized particles in the cooler region immediately behind the burning coal (Browne, 1990). The tobacco coal temperature reaches between 800–900°C, and the temperature of the smoke during a puff drops rapidly as it passes through the cigarette rod (Touey & Mumpower, 1957). Burning finer-cut tobacco creates an aerosol with smaller particles, which are easier to inhale. So changing the filler cut particle size can influence the aerosol and chemistry (Centers for Disease Control and Prevention, 2010). In general, a courser cut width of shredded tobacco increases the number of puffs per cigarette compared to finer cut widths. This is due to the fact that cigarettes containing more coarsely cut tobacco burn less efficiently than those with finer cut shreds (Geiss & Kotzias, 2007). CN packing particle size distribution was determined by measuring a random sample of the length and width of the processed cannabis particles in CN cigarettes (n = 6) from different batches (n = 3, n = 2/batch). The sorted CN cigarette plant material filler particle area distribution for the 50 sampled particles/cigarette is shown in Figure 1. Using this analysis we determined that 50% of the CN cigarette filler particles had an area between 0.04 mm^2 and 3 mm^2 and 50% had an area between 3 mm^2 and 90 mm^2. Approximately 90% of the CN particles measured were between 0.5 mm^2 and 25 mm^2 in area. The normalized

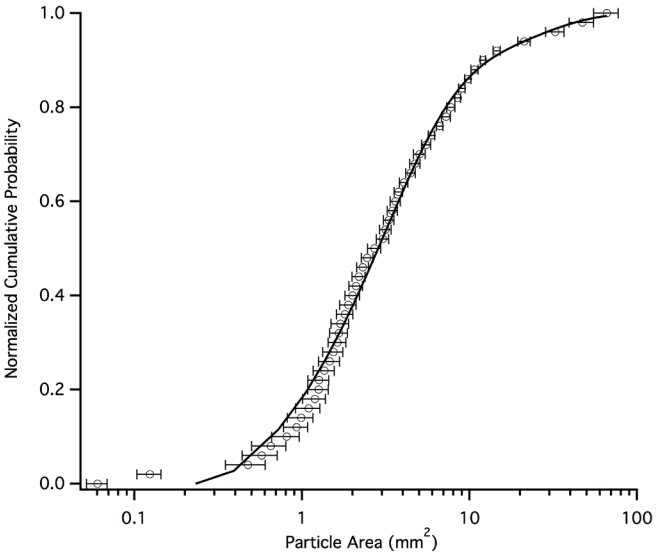

Figure 1. Cranfords cigarette normalized plant particle filler distribution probability. CN cigarettes were sampled (n = 6) for particle area distribution of the processed dried plant material and normalized to the largest particle observed. The minimum particles sampled were 0.04 mm^2 and the largest sampled were 90 mm^2. Coefficient values for the double exponential curve fit (solid black line) were y0 =1.0004, A1 = -0.89904, tau1 = 2.9679, A2 = -0.17192, tau2 =19,9972. Chi^2 p = 0.03 using IGOR pro software (Wavemetrics, Inc). The sorted particle measurements were averaged and plotted with standard error bars for each of the 50 particles measured/cigarette.

particle distribution represents visually selected samples of the particle size range for each cigarette and was not intended to represent the weighted size distribution of the particle areas within each cigarette. Randomized non biased imaging or sorting methods of cigarette particles to establish the relative weighted distribution of particle areas are planned for future experiments.

The inverted smoldering rates for CB, NP and CN cigarettes are shown in Figure 2. CB burned the slowest followed by NP and CN. The faster smoldering rate observed in the CN cigarettes may be due to the packing density and differences in the shape of the processed leaves and buds in the CN cigarette compared to the more uniform linear filler-cut tobacco packing. It is also possible that the CN cigarettes burn at a higher temperature resulting in a faster rate of smoldering, however preliminary measurements do not support this interpretation. Lastly, tobacco cigarettes contain additives that may retard smoldering rate. Additives, like humectants (e.g. polyethylene glycol) are added to alter combustion and smoke quality whereas CN cannabis cigarettes contain no additives. This is the first report of a method for processing cannabis buds and short leaves as cannabis cigarette filler for a machine-rolled CN cigarette. The process is an important determinant of plant filler particle size and smoldering rate, which, in turn can regulate the THCA to THC conversion during combustion and ultimately the inhaled THC dose.

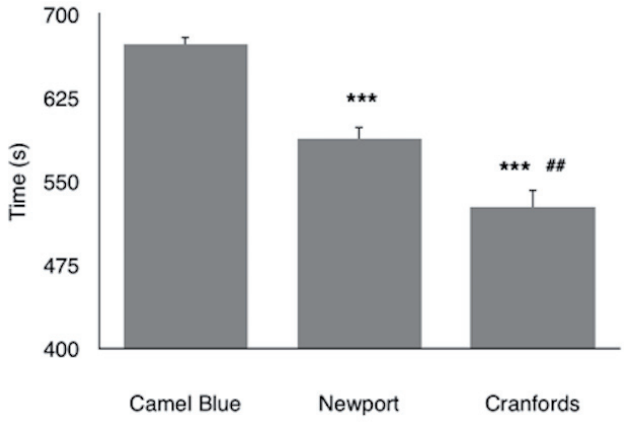

Figure 2. Inverted passive smoldering rate in tobacco and cannabis cigarettes. Camel Blue cigarettes (CB) burned at a rate of 673 sec/5 cm, Newport (NP) cigarettes burned significantly faster at a rate of 588 sec/5 cm (t-test; n=10, ***p<0.001), Cranfords (CN) cigarettes burned the fastest at a rate of 527 sec/5 cm compared to CB (t-test; n=10, ***p<0.001) and NP (t-test; n=10, ## p<0.01). Bars represent the average and standard error bars. Two-tailed, t-tests were performed using Excel for Mac version 15.12 (Microsoft).

Dataset 1. Raw data for Figure 1

http://dx.doi.org/10.5256/f1000research.7472.d109091

Six cigarettes were analyzed for sorted particle size distribution and the average and standard error are shown for the 50 particles sampled per cigarette.

Dataset 2. Raw data for Figure 2

http://dx.doi.org/10.5256/f1000research.7472.d109092

Ten cigarettes were analyzed for inverted passive smoldering temperature and the raw data are presented with averages and standard errors.

Data availability

F1000Research: Dataset 1. Raw data for Figure 1, 10.5256/f1000research.7472.d109091 (Cranford & Cooper, 2015a).

F1000Research: Dataset 2. Raw data for Figure 2, 10.5256/f1000research.7472.d109092 (Cranford & Cooper, 2015b).

Author contributions

JAC designed the protocol for manufacture and production of the cannabis and CN cigarettes and wrote the manuscript. DCC designed, executed and performed the experiments and statistical analysis and wrote the manuscript.

Competing interests

JAC is the owner and founder of Cranfords LLC, the manufacturer of Cranfords cannabis cigarettes. DCC has no declared competing interests.

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