Addictive Behaviors, Vol. 14, pp. 61–67, 1989
Printed in the USA.

0306-4603/89 $3.00 + .00

SOME PHYSICAL CHARACTERISTICS OF NIDA MARIJUANA CIGARETTES

L.D. CHAIT and J. PIERRI

Drug Abuse Research Center, Department of Psychiatry, The Pritzker School of Medicine, The University of Chicago

Abstract — Marijuana cigarettes of three different potencies (0.0%, 1.4% and 2.7% delta-9-tetrahydrocannabinol (THC) content) provided by the National Institute on Drug Abuse (NIDA) were compared on a variety of characteristics, including physical appearance, weight, burn rate, and deliveries of total particulate matter and carbon monoxide. Significant differences between the different potency cigarettes were obtained on most measures. These differences could be relevant to the design and interpretation of pharmacologic/toxicologic and behavioral studies conducted with these cigarettes. The possible basis for these observed differences, methods for minimizing some of them, and other potential problems related to the use of NIDA marijuana cigarettes are discussed.

For more than 15 years the National Institute on Drug Abuse (NIDA) (or, before its creation, the National Institute of Mental Health) has provided researchers with marijuana and other cannabis preparations. The marijuana, of Mexican origin, is grown at the University of Mississippi by the Research Institute of Pharmaceutical Sciences. The marijuana cigarettes provided by NIDA are manufactured on a modified tobacco cigarette machine and are stored partially dehydrated and frozen at the Research Triangle Institute, North Carolina. Marijuana of various potencies is available, including placebo, which is prepared by extracting active marijuana with alcohol until only trace amounts of cannabinoids remain.

For the past several years we have used NIDA marijuana cigarettes of various potencies in studying the subjective and behavioral effects of marijuana in humans. During the course of these studies, we observed certain characteristics of the cigarettes that could be relevant to the design and interpretation of research studies, particularly those that employ a placebo condition or attempt to maintain double-blind drug administration. These observations, along with the lack of published data on the physical characteristics of NIDA marijuana cigarettes, led us to conduct the experiments described in the present report.

METHOD

Cigarettes

Marijuana cigarettes of three potencies were used: placebo (P; 0.0% THC, batch #2055-34), intermediate (I; 1.4% THC, batch #2055-156) and high (H; 2.7% THC, batch #3430-48). All cigarettes were the same size (85 mm long × 25 mm circumference) and weighed approximately 800–900 mg. All cigarettes were humidified for 48 hours at room temperature before use, according to instructions provided by NIDA. For two experiments, commercial tobacco cigarettes of the same size (Pall Mall kings, unfiltered) were included for comparative purposes.

This research was supported by grant DA-03517 from the National Institute on Drug Abuse.

Requests for reprints should be sent to L.D. Chait, Box 411, Department of Psychiatry, the University of Chicago, Chicago, IL 60637.

Color

Soon after beginning work with the marijuana cigarettes, we observed that the different potency cigarettes could be easily distinguished from one another on the basis of the color of the plant material visible at the ends; P marijuana was brown, H marijuana was green, and I marijuana was a mixture of brown and green. The ability of one of the investigators to make these visual discriminations was examined in the following manner: 10 cigarettes of each potency were presented one at a time in random order to the blind observer, who attempted to identify each cigarette as P, I or H by visual examination.

Texture

While handling the cigarettes, we noticed that P cigarettes felt hard and brittle when compressed, whereas H cigarettes felt soft and "spongy." To validate this apparent difference, the same blind observer was presented with ten P and ten H cigarettes in random order. The observer (who wore dark glasses to prevent access to visual cues) attempted to identify each cigarette as P or H by squeezing them.

Weight

Ten cigarettes of each potency were randomly selected and weighed to the nearest mg, both before and after humidification.

Static burn rate

Ten cigarettes of each potency were studied. A 40-mm section of rod length was marked off by pencil on each cigarette. The cigarettes were lit, and the amount of time (in sec) taken for the 40-mm length to burn was recorded. Cigarettes were oriented horizontally during testing.

Puffs per cigarette

A measure of active burn rate can be obtained by determining the number of uniform puffs that can be taken from a fixed length of cigarette rod. Sixty-mm lengths of cigarette were marked off on ten cigarettes of each potency. Uniform size puffs (~85 ml) were taken from each cigarette with a rubber bulb syringe at 30-sec intervals until the 60-mm length had burned down. Cigarettes were oriented horizontally during testing. The number of puffs that could be taken from each cigarette was recorded.

Total particulate matter

The amount of TPM delivered by the marijuana cigarettes was determined for ten cigarettes of each potency. Cigarettes were smoked mechanically by placing them in plastic cigarette holders (Aquafilters), and positioning the "mouth" end of the holder at the intake nozzle of a vacuum cleaner. Cigarettes were mounted horizontally. A fixed length of cigarette rod (65-mm) was burned. With this setup, burn times varied from 31–84 sec. Particulate matter was collected on replaceable filter traps (Aquafilter) weighing from 101–171 mg (dry weight). Just before insertion into the holders, the filter traps were soaked in water, and the excess water shaken off. The used filter traps were allowed to air-dry for two days before being reweighed. The post- minus pre-smoking difference in filter trap weight was considered to represent TPM.

Based upon the results of this preliminary experiment, a systematic replication was performed. Several methodological refinements were made: (a) filter traps of more uniform size were used (mean weight = 127 mg, range = 116–143 mg); (b) burn

time was held constant (60 ± 5 sec) by moment-to-moment adjustments in flow rate using a Variac attached to the vacuum cleaner; (c) a tobacco cigarette was included as a reference. Ten cigarettes of each type were again studied.

Carbon monoxide

CO yields were determined from 18 marijuana cigarettes of each potency, and for comparative purposes, from 13 tobacco cigarettes (Pall Mall kings, non-filter). Cigarettes were lit mechanically with a syringe bulb. The lit cigarette was inserted into a hollow plastic holder (Aquafilter) which was connected to one end of a three-way stopcock. A 50-ml sample of smoke was drawn into a hypodermic syringe attached to another end of the stopcock. This "puff" was drawn over a period of about 5 sec. This 50-ml sample of smoke was then injected into a polyethylene gas sampling bag connected to the third end of the stopcock. Another 50-ml of ambient air was injected into the sampling bag to flush out the dead space of the apparatus. This sample of smoke was then diluted approximately 1:400 with ambient air so that the CO concentrations would fall within the calibration range of the CO meter used (Mini CO Model 1000, Catalyst Research Corporation, Baltimore). Samples were read immediately. CO levels are expressed in ppm. Only one puff was sampled from each cigarette to avoid changes in CO yield that have been reported to occur as cigarettes burn down and become shorter (Robinson & Forbes, 1975).

RESULTS

Color

All 30 cigarettes were correctly identified as P, I or H by the blind observer, demonstrating that the different potency cigarettes could be distinguished by the color of the plant material.

Texture

All 20 cigarettes were correctly identified as P or H, indicating that these two types of cigarettes could be distinguished from each other on the basis of handling.

Weight

The three types of cigarettes did not vary significantly in weight either before or after humidification. Mean weights (± SD) in mg were 854 ± 63, 818 ± 46 and 871 ± 68 before humidification, and 875 ± 65, 867 ± 49 and 915 ± 71 after humidification, for P, I and H cigarettes, respectively. However, the three types of cigarettes did differ in the increase in weight after humidification (one-way analysis of variance, $F(2, 27) = 204.75, p < 0.0001$). Mean increases in weight were 21, 49 and 44 mg for P, I and H cigarettes, respectively. Post-hoc comparisons (Tukey's HSD) showed that each of these means differed significantly from the others ($p < 0.05$). This finding suggests that P cigarettes absorbed less than half as much water during humidification as the other two potency cigarettes.

Static burn rate

Burn rates were inversely related to potency: Mean (± SD) burn times in sec for the P, I and H cigarettes were 461 ± 45, 490 ± 43 and 537 ± 27, respectively, $F(2, 27) = 9.53, p < 0.001$). These values convert to corresponding burn rates of 5.2, 4.9 and 4.4 mm/min. Post-hoc comparisons (Tukey's HSD) indicated that the burn time of the H cigarettes was significantly longer than those of the other two potencies ($p < 0.05$).

Table 1. Summary of results

Measure	Cigarette potency (% THC)		
	P (0.0)	I (1.4)	H (2.7)
Dry weight (mg)	854	818	871
Humidified weight (mg)	875	867	915
Weight change (mg)	21	49	44
Burn time (sec)	461	490	537
Puffs per cigarette	8.9	8.2	9.4
TPM (mg) 1st expt	35	49	54
2nd expt	31	46	64
CO (ppm)	113	98	76

Values not underscored by the same line are significantly different from each other ($p \leq 0.05$; Tukey's HSD test).

Puffs per cigarette

The mean (± SD) number of puffs that could be taken from the three types of cigarettes, in order of increasing potency, was 8.9 ± 1.1, 8.2 ± 1.2 and 9.4 ± 0.8. These values were not significantly different ($F(2, 27) = 3.17, p < 0.10$).

Total particulate matter

In the first experiment, it appeared that TPM was directly related to potency. Mean values (± SD) in mg were 35 ± 11, 49 ± 11 and 54 ± 25 for P, I and H cigarettes, respectively. However, these differences were not significant ($F(2, 27) = 3.30, p < 0.10$).

A large source of variation in these data was found to be due to a strong correlation between burn time and TPM. Pearson product-moment correlation coefficients between these two variables for the three types of cigarettes were 0.80, 0.91 and 0.90 ($p < 0.01$ in each case). Burn time was not controlled in this experiment, and the variability in burn times was probably due at least in part to variations in the size of the filter traps used to collect TPM. Presumably, the larger the filter trap, the more resistance to draw it provided, which in turn led to longer burn times.

For this reason, we decided to repeat the experiment, incorporating several methodological changes (see Method for details). With this refined procedure, TPM was found to vary directly with marijuana potency ($F(3, 36) = 28.76, p < 0.001$). Mean values (± *SD*) in mg were 31 ± 7, 46 ± 10, 64 ± 13 and 28 ± 7 for P, I, H and tobacco cigarettes, respectively. Each of these means differed significantly from the others, with the exception of the P and tobacco cigarettes (Tukey's HSD test, $p < 0.05$). The TPM yield obtained here for the tobacco cigarette (28 mg) is in good agreement with the value reported by the FTC for this brand of cigarette (23.5 mg).

Carbon monoxide

The different potency marijuana cigarettes also differed in CO yield ($F(2, 51) = 8.90, p < 0.001$). Mean values (± *SD*) in ppm for P, I and H cigarettes, respectively, were 113 ± 34, 98 ± 23 and 76 ± 20. The value for H cigarettes was significantly less than that for P and I cigarettes (Tukey's HSD, $p < 0.05$). The corresponding CO yield for the tobacco cigarettes was 63 ± 13 ppm.

The major results are summarized in Table 1.

DISCUSSION

An ideal marijuana placebo would be identical to active marijuana in every respect except that the placebo would not contain any psychoactive cannabinoids. Assuming that the marijuana provided to us by NIDA is representative, the present results indicate that the placebo marijuana produced by NIDA falls short of this ideal. For some research purposes, the differences presented here between the different potencies of marijuana may not be particularly important. However, these findings should caution researchers not to assume that different results obtained with placebo and active marijuana can necessarily be attributed to differences in cannabinoid content.

Our human studies involve repeated testing of subjects with both placebo and active marijuana. On the basis of the results reported here, we have adopted the following procedures in an attempt to maintain double-blind dosing conditions: A small plug of plant material (~ 5 mm) is knocked out of each end of the cigarette. The ends of the cigarette are then closed by folding in the cigarette paper. The cigarette is then cut in half. Before being presented to the subject, the open (cut) end of the (now half-length) cigarette is inserted into a hollow plastic cigarette holder. The cigarette in the holder is lit mechanically by the experimenter and then handed to the subject. Subjects are allowed to take only two puffs from each cigarette. With this procedure subjects never see the color of the marijuana nor directly handle the cigarettes. The plastic holder prevents subjects from squeezing and possibly occluding the end of the cigarette with their fingers or lips. In addition, the tar stains that are deposited on the inside of the holders can be rated on a colorimetric scale to provide a semi-quantitative estimate of mouth-level smoke exposure (Chait, Evans, Grant, Kamien, Johanson, & Schuster, 1988). Having subjects take only two puffs from half-length cigarettes reduces the possibility of subjects using differences in burn rate to distinguish between placebo and active marijuana cigarettes. Using short cigarettes also ensures more consistent puff-to-puff delivery of smoke components, since it is well-established that the concentrations of smoke components change (usually increase) with successive puffs on a cigarette (Davis, McDaniel, Cadwell, & Moody, 1984; Huber et al., 1979; Robinson & Forbes, 1975).

We found that total particulate matter delivery increased with increasing THC content. This increase cannot be accounted for solely by the difference in THC content, however. The high-potency cigarettes contained (by calculation) about 18 mg of THC in the portion that was burned during testing. Yet these cigarettes delivered on average 33 mg more TPM than the placebo cigarettes (second experiment, Table 1). This difference probably reflects the fact that other organic constituents were removed from the original marijuana during the alcohol extraction procedure used to prepare the placebo marijuana (Rosenkrantz & Fleischman, 1979). Increased TPM yield with increased cigarette THC content was also reported by Rosenkrantz and Fleischman (1979), who also used NIDA marijuana, but not by Rickert, Robinson, and Rogers (1982), who used unextracted Colombian marijuana obtained from another source. Our finding that active marijuana produces more TPM than a standard high-yield tobacco cigarette also agrees with results reported by Rosenkrantz and Fleischman (1979), Fehr & Kalant (1972) and Rickert et al. (1982). Huber et al. (1979), however, found that NIDA marijuana cigarettes (2.0% THC) produced only half as much TPM as a standard tobacco cigarette. The reason for this discrepancy is unclear.

The present findings indicate that marijuana CO yield is inversely proportional to THC content (Table 1). Rosenkrantz and Fleischman (1979) also state that placebo marijuana produces more CO than active marijuana, and data from Rickert et al. (1982) suggest that 1.3%-THC marijuana yields more CO than 4.5%-THC marijuana. Our finding that marijuana cigarettes produced somewhat greater CO yields than a standard tobacco cigarette differs from results obtained by others showing either equivalent yields (Rosenkrantz & Fleischman, 1979) or lower yields with marijuana (Rickert et al., 1982; Huber et al., 1979). These disparate results may be due to different procedures used in measuring CO or to the different tobacco cigarettes used in the four studies.

In the present study placebo cigarettes produced on average 49% more CO than the 2.7%-THC cigarettes. This result is supported by data obtained in our laboratory from human smoking studies. In one study (Chait, Fischman, & Schuster, 1985) five uniform puffs from placebo cigarettes increased expired air CO levels by 6.5 ppm, whereas the same number of puffs from 2.9%-THC cigarettes increased CO levels by 4.3 ppm, a difference of 51%. In a more recent study (Chait et al., 1988) four uniform puffs from placebo cigarettes raised expired air CO levels by 4.3 ppm, compared with 3.1 ppm after four puffs from 2.7%-THC cigarettes, a difference of 39%. Thus, results from both human and mechanical smoking studies from our laboratory have consistently shown that placebo marijuana produces 40–50% more CO than high-potency marijuana. A recent study from another laboratory (Hecht & Vogt, 1985), in which subjects smoked placebo, low-potency or high-potency marijuana cigarettes, reported no differences in post-smoking expired air CO levels among the three different potency cigarettes. However, the methodology and results were not described in sufficient detail to allow proper evaluation of this study.

Presumably, most of the differences we observed between the placebo and active marijuana cigarettes are the result of the alcohol extraction process used to remove cannabinoids from the marijuana. Many other alcohol-soluble plant constituents would also no doubt be removed by this extraction, some of which could have significant biological activity. Therefore, it cannot safely be assumed that active and placebo marijuana differ only in cannabinoid content.

Many of the results we obtained are consistent with the possibility that the placebo cigarettes had a lower moisture content than the THC-containing cigarettes. Low moisture cigarettes have been associated with fast burn times and high per-puff CO yields (Robinson & Forbes, 1975). The placebo marijuana cigarettes increased in weight by only 2.5% after humidification, compared with 5–6% for the other potency cigarettes. Perhaps the alcohol-extraction process adversely affects the ability of placebo cigarettes to absorb additional moisture.

Another factor that could be relevant concerns the age of the marijuana cigarettes. The placebo marijuana provided to us was harvested in 1971, nearly 15 years before the present studies were conducted. The other potency cigarettes were somewhat "fresher," being harvested in 1978–79 (1.4%-THC) and 1981–82 (2.7%-THC). The marijuana is stored frozen and at reduced moisture content in order to retard degradation, and THC concentrations remain fairly stable for long periods of time under these conditions (Turner, Hadley, Fetterman, Doorenbos, Quimby, & Waller, 1973). Nevertheless, over such a long period of time, some degree of chemical and physical degradation of the plant material is inevitable. The age of the marijuana may also be related to the consistently low verbal ratings that our subjects assign to the NIDA marijuana. Nearly all subjects report that the marijuana is inferior in sensory qual-

ities (taste, harshness) than the marijuana that they smoke outside the laboratory. Some have stated that it was the worst marijuana they had ever sampled, or that it tasted "chemically-treated."

In summary, we have found significant differences in some physical characteristics between NIDA marijuana cigarettes of different potencies, differences which could have important implications for pharmacologic/toxicologic and behavioral studies. Other "deficiencies" of these cigarettes have been noted by other investigators (Rosenkrantz & Fleischman, 1979; Huber et al., 1979). Because of the nature of the plant material, it is reportedly difficult to manufacture placebo and active marijuana cigarettes of quality and consistency comparable to commercial tobacco cigarettes. Nevertheless, as researchers, we would certainly appreciate any efforts directed toward improving the quality of marijuana cigarettes provided by NIDA, as well as more detailed analytical data on the physical and chemical characteristics of the cigarettes, as have been published for the University of Kentucky and National Cancer Institute series of tobacco research cigarettes (Benner, 1970; Gori, 1980).

REFERENCES

Benner, J.F. (1970). *Tentative summary of leaf and smoke analysis of University of Kentucky reference and alkaloid series cigarettes.* Proceedings of the Tobacco and Health Conference, Conference Report #2. Lexington: University of Kentucky.

Chait, L.D., Fischman, M.W., & Schuster, C.R. (1985). 'Hangover' effects the morning after marijuana smoking. *Drug and Alcohol Dependence,* **15,** 229–238.

Chait, L.D., Evans, S.M., Grant, K.A., Kamien, J.B., Johanson, C.E., & Schuster, C.R. (1988). Discriminative stimulus and subjective effects of smoked marijuana in humans. *Psychopharmacology,* **94,** 206–212.

Davis, K.H., McDaniel, I.A., Cadwell, L.W., & Moody, P.L. (1984). Some smoking characteristics of marijuana cigarettes. In S. Agurell, W.L. Dewey, & R.E. Willette (Eds.), *The cannabinoids: Chemical, pharmacologic, and therapeutic aspects* (pp. 97–109). Orlando: Academic.

Fehr, K.O., & Kalant, H. (1972). Analysis of cannabis smoke obtained under different combustion conditions. *Canadian Journal of Physiology and Pharmacology,* **50,** 761–767.

Gori, G.B. (Ed.). (1980). *Report No. 4 — Toward less hazardous cigarettes: The fourth set of experimental cigarettes.* National Cancer Institute, Smoking and Health Program.

Hecht, E., & Vogt, T.M. (1985). Marijuana smoking: Effect on expired air carbon monoxide levels. *The International Journal of the Addictions,* **20,** 353–361.

Huber, G.L., Pochay, V.E., Shea, J.W., Hinds, W.C., Weker, R.R., First, M.W., & Sornberger, G.C. (1979). An experimental animal model for quantifying the biologic effects of marijuana on the defense system of the lung. In G.G. Nahas & W.D.M. Paton (Eds.), *Marijuana: Biological effects* (pp. 301–328). Oxford: Pergamon Press.

Rickert, W.S., Robinson, J.C., & Rogers, B. (1982). A comparison of tar, carbon monoxide and pH levels in smoke from marihuana and tobacco cigarettes. *Canadian Journal of Public Health,* **73,** 386–391.

Robinson, J.C., & Forbes, W.F. (1975). The role of carbon monoxide in cigarette smoking. I. Carbon monoxide yield from cigarettes. *Archives of Environmental Health,* **30,** 425–434.

Rosenkrantz, H., & Fleischman, R.W. (1979). Effects of cannabis on lungs. In G.G. Nahas & W.D.M. Paton (Eds.), *Marijuana: Biological effects* (pp. 279–299). Oxford: Pergamon Press.

Turner, C.E., Hadley, K.W., Fetterman, P.S., Doorenbos, N.J., Quimby, M.W., & Waller, C. (1973). Constituents of cannabis sativa L. IV: Stability of cannabinoids in stored plant material. *Journal of Pharmaceutical Sciences,* **62,** 1601–1605.