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Potency of Δ^9 -THC and Other Cannabinoids in Cannabis in England in 2005: Implications for Psychoactivity and Pharmacology*

ABSTRACT: Gas chromatography was used to study the cannabinoid content ("potency") of illicit cannabis seized by police in England in 2004/5. Of the four hundred and fifty two samples, indoor-grown unpollinated female cannabis ("*sinsemilla*") was the most frequent form, followed by resin (hashish) and imported outdoor-grown herbal cannabis (marijuana). The content of the psychoactive cannabinoid Δ^9 -tetrahydrocannabinol (THC) varied widely. The median THC content of herbal cannabis and resin was 2.1% and 3.5%, respectively. The median 13.9% THC content of *sinsemilla* was significantly higher than that recorded in the UK in 1996/8. In *sinsemilla* and imported herbal cannabis, the content of the antipsychotic cannabinoid cannabidiol (CBD) was extremely low. In resin, however, the average CBD content exceeded that of THC, and the relative proportions of the two cannabinoids varied widely between samples. The increases in average THC content and relative popularity of *sinsemilla* cannabis, combined with the absence of the anti-psychotic cannabinoid CBD, suggest that the current trends in cannabis use pose an increasing risk to those users susceptible to the harmful psychological effects associated with high doses of THC.

KEYWORDS: forensic science, herbal cannabis, marijuana, *sinsemilla*, resin, hashish, *skunk*, potency, cannabinoid, Δ^9 -tetrahydrocannabinol, cannabidiol, cannabiol

Cannabis is the most frequently used illicit drug in the UK (1). Of the 109410 drug seizures in England and Wales in 2003, 72% were of cannabis (2). The material is primarily used for recreational purposes, but is also employed illegally to treat the symptoms of multiple sclerosis and a wide range of other medical conditions, especially those requiring pain-relief (3,4). The drug is prepared from the plant *Cannabis sativa* L., the principle active ingredients being the cannabinoids. This group of at least sixty terpenophenolic compounds is unique to cannabis. Within the plant these compounds exist as cannabinoid acids (e.g., cannabidiolic acid [CBDA]), but as the plant material ages or is heated the acids decarboxylate into the neutral forms (e.g., CBDA \rightarrow CBD) (5). This article refers to each cannabinoid by its neutral form.

Tetrahydrocannabinol is the main psychoactive ingredient in cannabis and, according to the British Medical Association (6), this cannabinoid is also responsible for many other pharmacological properties of cannabis. However, other cannabinoids have also demonstrated a range of pharmacological activities (7). CBD has pharmacological properties but is not psychoactive. Based on pre-clinical and clinical data, CBD is notable for its ability to antagonize the psychoactive effect of THC (8–11). Its presence would be suspected of lowering the recreational value of cannabis.

A number of studies have reported that those who consistently consume large amounts of cannabis have an increased risk of later developing schizophrenia-like psychoses (12,13). Consumers using

cannabis lacking the antipsychotic cannabinoid CBD may have been at greater risk. Smith (14) highlighted that high potency cannabis products lacking CBD have the potential to be more harmful, and suggested that more research was required to investigate how cannabis type or variety affects clinical disorders. Recognizing this same fact, the United Nations Office on Drugs and Crime 2006 World Drug Report stated that *where possible it would be advisable to track both THC and CBD levels in future evaluations of "potency"* (15). This is believed to be the first large-scale UK study to do so.

Within the UK the illicit drug commonly exists as either a resin (more commonly known as hashish in the USA) or a dried-plant preparation. Within the latter category there are two distinct types of material circulating. One form is imported into the UK, from a number of tropical or subtropical countries, and contains floral and foliar material from outdoor grown pollinated female plants. This type is commonly referred to as *herbal cannabis* in the UK and as *marijuana* in the USA. The more frequent type of dried-plant material in the UK is referred to in this note using the internationally recognized term *sinsemilla* (Spanish derivation meaning without seeds). This form is predominantly grown indoors using all-female plants and highly technical equipment. *Sinsemilla* is more typically referred to as *skunk* in the UK. Many publications on cannabis, including official UK Home Office reports (2), do not differentiate between these two forms of cannabis dried-plant material. In such cases they are both commonly referred to as *herbal cannabis*.

Previous studies have shown that the content of THC and other major cannabinoids varies widely in illicit cannabis (16). Evidence also suggests that the average potency of the material in the UK has risen steadily in recent years (17). The aim of this study was to determine the relative popularity and cannabinoid content of the different forms of illicit cannabis, enabling assessment of both their differing medicinal efficacy and potential harm. This was achieved by analysing the cannabinoid content of four hundred and fifty two

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samples, seized during 2004/5 by police constabularies in five geographically spread localities. These areas covered communities with a range of socio-economic and racial mixes and varying opportunities for illegal import through nearby ports.

Methods

Acquisition and Identification of Samples

Samples were collected from the police property stores of five constabularies – Derbyshire, Kent, London Metropolitan, Merseyside and Sussex. All samples were collected during a range of dates in 2005, some of which had been stored at room temperature ($\sim 20^{\circ}\text{C}$) for up to a year. The majority of the materials had been seized from users and suppliers “on the street.” The remainder were found during searches of property suspected of being involved in cannabis production or consumption.

The materials were assessed visually, using a simple light microscope where necessary, and the form of the cannabis sample was established. Four categories were identified:

Cannabis Resin (Hashish)—This consists of the glandular trichomes and other fine particles collected from the inflorescences and upper leaves and bracts. The material is compressed into hard blocks prior to importation. All samples were dark brown in color. These samples varied in shape and size and, when present in sufficient quantity, these generally had a light characteristic odor.

Herbal Cannabis (Marijuana)—As adopted by King et al. (17), this category included imported dried plant material collected from plants grown outdoors. The material was light to dark brown in color. The glandular trichomes were always brown in color because of aging (18). Seeds were frequently present. The material was sometimes in loose form, but was also frequently encountered in hard blocks where it had been compressed to reduce volume during importation. The material had a light fragrant odor. Fungal mycelium was occasionally visible, suggesting that decay had occurred at some point during importation or storage.

Sinsemilla (Skunk)—This form of cannabis was light green or gray-green in color. The material consisted of resinous female floral material only. Close examination often revealed where bracts and leaves had been physically removed. Large intact sections of inflorescence, up to several grams in weight, were sometimes present. More commonly, the material had been loosely ground in preparation for smoking. Seeds were always absent as a result of the all-female crops being grown in the absence of pollen. Glandular trichome color varied between crystal clear, white, and light brown. The odor was clearly stronger than that of resin and herbal cannabis. There was no visible sign of fungal deterioration. This pungent, light material is generally regarded as having been grown in the UK, but some will possibly have entered the UK from mainland Europe.

Cannabis Powder—Some herbal cannabis and sinsemilla samples were recovered from portable cannabis grinders, that are used to break herbal cannabis and sinsemilla into a suitably fine texture for smoking. More complex grinders included a fine metal mesh within the construction. Glandular trichomes dislodged from the plant during grinding could fall through this sieve and be collected in a separate chamber within the device. Glandular trichomes are the principal or sole site of cannabinoid biosynthesis (19). One grinder was found with *c.* 1 cm^{-3} of separated yellow powder. This consisted almost entirely of glandular trichome resin heads and stalks.

Previous studies on illicit cannabis potency in the UK have included analyses of hash oil. This liquid preparation is made by dissolving, and subsequently concentrating, cannabis extracts in an organic solvent (20,21). No such samples were identified during this study.

Many samples were seized which consisted of a mixture of cannabis and tobacco. All were excluded from this study. Three seized suspected-cannabis samples were also analyzed and found to be plant material other than cannabis or tobacco.

Chromatographic Analysis

The analysis method used in this study was that developed by de Meijer et al. (5) for the validated identification and quantification of a range of cannabinoids.

Statistical Analysis

Analyses of variance were performed to test the significance of the differing potencies of samples between constabularies.

The Kolgomorov–Smirnov test was used to compare the distributions of sinsemilla potencies between those found in this study in 2005 and that reported for 1996/8 by King et al. (17). The change in average potency was assessed using the Wilcoxon rank-sum test and the Hodges-Lehmann estimator used to estimate the size of the difference.

Results and Discussion

Pattern of Distribution of Sinsemilla, Herbal Cannabis, and Resin Across the Regions

Sinsemilla was the most common form found overall, accounting for 55% of the samples seized. However, differences were found between regions. In Kent, resin accounted for 85 of the 143 samples (59%), possibly because of importation through the major ports in this region. Herbal cannabis is presently the most common form of cannabis in the USA (15). In contrast, this study reveals that this type is the least common in the UK. Little or no herbal cannabis was identified in four of the regions, but it accounted for 30 of the 158 samples (19%) seized in the London Metropolitan area.

Comparison of Potency Levels of Cannabis Resin and Sinsemilla Between Regions

There were large differences in the mean potencies of resin between regions. Resin seized in Sussex (6.6%) and Derbyshire (5.4%) had significantly higher mean THC content ($p < 0.05$) than that seized in Kent (4.2%), London (3.6%) or Merseyside (2.8%). Without knowledge of the sources of the resin in each area it is not possible to explain why these differences existed, or if they are consistent.

There were proportionally smaller but statistically significant differences in mean THC content of sinsemilla seized in different areas. The highest mean THC content was found in the Derbyshire region (16.3%). This material was significantly more potent ($p < 0.05\%$) than that seized in London (mean 12.9%). The remaining counties returned mean sinsemilla potencies values between these two extremes, the differences in potency not being statistically significant ($p = 0.05$). Because of the small number or absence of herbal cannabis samples in most regions, a meaningful comparison of herbal cannabis potency levels between regions was not possible.

TABLE 1—The median and the range of potencies of cannabinoids (% w/w) in resin ($n = 169$), herbal cannabis ($n = 35$), sinsemilla ($n = 247$) and cannabis powder ($n = 1$), seized in five constabularies in England in 2004/5 (total $n = 452$).

Type	THC	CBD	CBC	THCV	CBG	CBN
Resin						
Median	3.54	4.17	0.34	0.10	0.29	1.55
Minimum	0.44	0.36	<0.10	<0.10	<0.10	0.38
Maximum	10.76	6.97	0.66	0.29	1.05	4.30
Herbal						
Median	2.14	<0.10	0.22	0.17	0.21	0.55
Minimum	0.28	<0.10	<0.10	<0.10	<0.10	<0.10
Maximum	11.81	1.97	0.42	0.43	0.76	3.62
Sinsemilla						
Median	13.98	<0.10	0.20	<0.03	0.41	0.16
Minimum	1.15	<0.10	<0.10	<0.10	<0.10	<0.10
Maximum	23.17	0.56	1.41	2.74	2.16	2.98
Powder	40.63	0.18	0.41	0.29	1.59	0.57

The cannabinoids studied, in addition to THC, CBD and CBN, were CBC (cannabichromene), THCV (tetrahydrocannabivarin) and CBG (cannabigerol).

The Pattern and Range of Potencies of Resin, Herbal Cannabis, and Sinsemilla

The potency of resin samples varied widely from almost 0% THC up to nearly 11% (Table 1). The majority of the samples were at the weaker end of this range. 40% had a THC content of <2% THC, and more than 80% had <6%. The range of potencies in herbal cannabis was similar. The maximum THC content found was nearly 12% but approximately 90% had a content of <6%.

Sinsemilla potency ranged from about 1% to 23%, the majority being toward the high end of this range.

Comparison of the Variation in Cannabinoid Profiles of Cannabis Samples

The range of potencies of a number of cannabinoids, including THC, in resin, herbal cannabis, sinsemilla and cannabis powder is shown in Table 1.

The range of cannabinoids (the cannabinoid profile) in most samples of sinsemilla showed minimal presence of cannabinoids other than THC. The tetrahydrocannabivarin (THCV), cannabigerol (CBG), and cannabinol (CBN) content occasionally exceeded 2%, but this was approximately one-tenth of the maximum potency recorded for THC. The CBD content of sinsemilla was typically very low and fell below detectable levels (0.1%) in the majority of samples.

THC was also the dominant cannabinoid in herbal cannabis and CBD levels were mostly below the detectable threshold (0.1%). In both sinsemilla and herbal cannabis, the THC content was typically an order of magnitude greater than that of CBC, THCV, or CBG. CBN levels were much higher in herbal cannabis than in sinsemilla. This is at least partly because of the length of time that herbal cannabis encounters on its route to the UK. A long transport period would favor the breakdown of THC to the catabolite CBN (22).

Cannabis resin had a very different cannabinoid profile to herbal cannabis and sinsemilla. CBD was the dominant cannabinoid in this material, with average THC contents being marginally less. CBN was present in much higher quantities than in herbal cannabis or sinsemilla. These contrasting cannabinoid ratios are very similar to those found in US cannabis samples by ElSohly et al. (12) between 1980 and 1997.

Research suggests that the production of THC or CBD, from the common precursor CBG, is closely controlled by two co-dominant

alleles at a single locus (5). As a result, cannabis plants can be identified as belonging to any one of three chemotypes. These can be THC dominant, CBD dominant or containing an approximately equal mixture of the two (5,23,24). The majority of the cannabis resin would appear to be prepared from landrace populations of plants which contain all three chemotypes. Herbal cannabis and sinsemilla appear almost entirely derived from the THC dominant chemotype.

Cannabis resin samples showed very variable contents of THC (0.44–10.76%) and CBD (0.36–6.97%). The ratio of these cannabinoids within individual samples varied widely. As CBD is reported to attenuate the psychoactive effects of THC, the wide range of THC:CBD ratios would be expected to variably alter the potential psychoactive and pharmacological effects of the THC within the resin. This emphasizes that the potential psychoactive and pharmacological properties of cannabis resin should not be simply judged by the THC content alone. The remarkably uniform appearance of the resin samples gave no indication of the variable cannabinoid content and profile.

The cannabis powder retrieved from the herb grinder was the most potent of the samples analyzed (40.6% THC) (Table 1). This material had been prepared using a very simple piece of equipment, and this illustrates that extremely potent cannabis preparations are readily available.

Increasing Potency Levels

The mean THC content of imported herbal cannabis in this study (3.1%) was lower than the 4–5% observed by the UK Forensic Service between 1995 and 1999 (15). Little inference regarding potency trends can be drawn from this because of the small number of samples in both studies. The mean THC content of resin (3.7%) was typical of that found previously, where potency levels varied from approximately 3–6% THC between 1998 and 2002.

As stated earlier, CBN is the major breakdown product of THC, the conversion of THC to CBN being accelerated in hot, damp, and or bright conditions (22). The low median CBN content in sinsemilla cannabis suggests that the storage conditions in the police facilities satisfactorily maintained the stability of the cannabis samples. The higher levels of CBN in herbal cannabis and cannabis resin was therefore probably not attributable to conditions in police storage, and was most likely attributable to unfavorable conditions during outdoor propagation, storage, manufacture, and transportation.

The mean sinsemilla potency of 13.3% is higher than that reported by the Forensic Science Service over the period 1995 to 2003 (17). During this period the reported mean THC content rose from approximately 6.0–12.5%. This supports the belief that sinsemilla potency in the UK is increasing, although at nothing like the rate observed in the mid to late Nineties.

In both this study and that performed by the Forensic Science Service the THC content of samples ranged from <2% THC to >20%. The range of sinsemilla potency levels observed in each study is compared directly in Fig. 1.

The data in Fig. 1 were analyzed using the Kolmogorov–Smirnov test for different distributions. This showed that the two distribution curves were significantly different ($p < 0.0001$). A Wilcoxon Rank Sum test showed that the potency levels in 2005 were significantly higher than those in 1996/8 ($p < 0.0001$). A Hodges-Lehman Estimate of median difference suggests an increase of 4.86% THC in the median potency between the 1996/8 data and the 2005 data (CI = 3.77, 5.54).

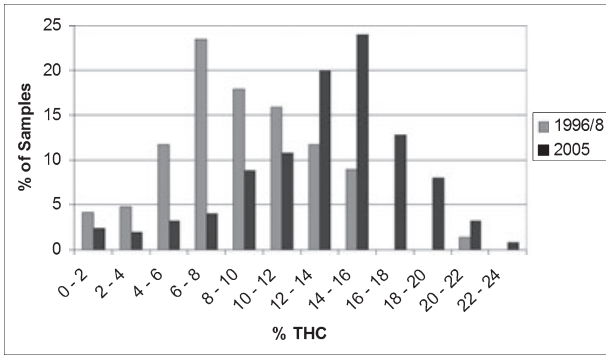


FIG. 1—A comparison of the ranges of THC contents of *Sinsemilla* seized in the UK and analyzed by the Forensic Science Service in 1996–8 ($n = 145$) and samples seized by police in Derbyshire ($n = 15$), Kent ($n = 58$), London Metropolitan ($n = 96$), Merseyside ($n = 44$) and Sussex ($n = 34$) in 2004/5 (total $n = 247$).

Large increases in cannabis potency achieved in the 1970s were largely attributed to the achievements of cannabis breeders (25). Many cultivars produced in the 1970s and 1980s are still widely used. Although seeds of new cannabis cultivars are continually produced in large numbers (26) these do not appear to produce plants of significantly higher THC content (Potter, unpublished data). The rise in reported potency is more likely due to increasing expertise amongst the illicit UK growers in recent years. During this period there has been a large increase in the number of retail outlets selling cannabis seeds and sophisticated growing equipment. Many books, videos, and DVDs have been produced, educating growers how to maximize cannabis potency. The internet has facilitated on-line purchasing of these items. Expert web pages and focused “chat-rooms” have provided easily accessible advice. During this period, the UK Government and Police express the opinion that the production and dealing of cannabis have not always been targeted sufficiently vigorously (27).

Conclusions

This study suggests that cannabis in England in 2005 remains a very variable drug with unpredictable pharmacological and psychological activity. The potency (THC content) of the cannabis varies widely, as does the content of other cannabinoids, especially in herbal cannabis and cannabis resin. The average potency within the country appears to be increasing, but large variations remain within and between different areas of the country.

CBD affects the pharmacological qualities of THC and reduces its psychoactive potential. The relative proportions of THC and CBD in resin are wide ranging, supporting the view that the potential effects of resin cannot be judged by measuring the THC content alone. The resin samples were all similar in appearance and gave the user no indication of their cannabinoid content.

Of the three principle forms of cannabis, *sinsemilla* commonly had the highest THC content and almost totally lacked CBD. Had CBD been present it would have reduced the psychoactive potential of this material. In addition to having increased in potency, *sinsemilla* also appears to have become the most widely used form of cannabis. The current trends in cannabis use suggest that those susceptible to the harmful psychological effects associated with THC are at ever greater risk. This is due to the combined rise in potency and popularity of *sinsemilla* and the absence of CBD in this product.

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