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The Influence of Electrostatic Properties on the Punch Sticking Propensity of Pharmaceutical Blends

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ABBREVIATIONS

API	Active pharmaceutical ingredient
CDTA	Charge Decay Time Analyser
DC	Direct Compression
Hz	Hertz
MASS	Material Adhesion Screen for Sticking
MgSt	Magnesium stearate
nC	nanoCoulomb
N/R	Not reached
RH	Relative humidity
RPM	Rotations per Minute
SD	Standard deviation
$t_{1/e}$	Time taken for the surface potential to decay to 1/e (36.8%) of the initial value
$t_{10\%}$	Time taken for the surface potential to decay to 10% of the initial value
Vs	Initial surface potential difference

1. INTRODUCTION

Tablets are the most popular oral solid dosage form in the pharmaceutical industry due to their convenience to the patient, ease of manufacture and their ability to deliver a wide range of therapeutic doses [1-4]. The most efficient tableting process is direct compression (DC), in which the excipients and active pharmaceutical ingredient (API) are thoroughly mixed to form a homogenous blend and then compacted without the need for granulation [1, 3]. For this process to be successful, the excipients and API need to have suitable physical properties including low punch sticking propensity [1, 5]. However, as new drugs are developed, instances often arise where failures in the manufacturing process occur due to high punch sticking propensity of the input materials [1, 6]. The sticking of tablets to punch faces is a serious problem in tablet production, causing considerable loss of time and money [6-10]. In the worse cases, strong adhesion to the upper punch may lead to complete sticking of a tablet to the punch. Subsequent compression of the tablet with a new filling of the die may lead to a breakdown of the tableting machine. However, in most cases the outcome is less severe as sticking only leads to adhesion of a powder layer onto the punch surface. Nevertheless, it may result in early termination of the tableting process for cleaning purposes. In addition, sorting and disposal of tablets exhibiting rough surfaces and incomplete or missing debossing is wasteful and costly [8]. Despite the fact that numerous studies have already been conducted to elucidate the fundamental causes of tablet sticking [11-24], it is still one of the most common problems observed during production-scale tableting [6]. Therefore, tablet manufacturers are still searching for universally applicable measures to prevent and/or solve sticking problems more efficiently.

During pharmaceutical powder processing operations, powder particles frequently come into contact with each other and with the walls of the processing equipment and become electrostatically charged by a process known as triboelectrification [1, 25-34]. Particle triboelectrification has been suggested as a potential cause of punch sticking [32, 35], however, little work has been reported in this area.

Ghori *et al.* recently studied the relationship between triboelectric charging and surface adhesion for binary mixtures of flurbiprofen and different cellulose ethers in powders with varying particle size [36]. A reduction in susceptibility towards triboelectric charging showed a linear relationship ($R^2 = 0.81-0.98$) with surface adhesion. However, most triboelectric studies reported in the literature including the study highlighted above, used a triboelectric charge measurement apparatus based on a shaking concept [37]. Triboelectrification of powder samples inside a horizontally shaking container was achieved by particles impacting and sliding against the surfaces for certain time periods at a vibration frequency of 20 Hz with the amplitude of vibrations fixed at 8.9 mm. The triboelectric charge was then measured by pouring the charged powder particles into a Faraday cup, connected to an electrometer [36]. However, a limitation of the study is that pouring itself may result in additional triboelectrification of the powders [38].

A Charge Decay Time Analyser (CDTA) (JCI155 v6, Chilworth Technology Ltd. Southampton, UK) is an instrument which has been suggested as a robust, operator independent means of determining the electrostatic charging propensity of materials [38-41]. A high voltage corona discharge is used to deposit charge onto the surface of a sample to be tested. A fast response electrostatic field meter measures the surface potential difference generated by this charge and how quickly the resultant voltage falls as charge decays from the sample over time as shown in Figure 1 [38]. If the corona discharge is kept at a constant value, the initial surface potential post corona charging (V_s) will indicate the susceptibility of a powder to pick up static charge, with the greater the initial value, the greater the charging propensity [38]. In addition, the charge decay rate, as quantified by the Time to 10% ($t_{10\%}$) and Time to $1/e$ ($t_{1/e}$) values as shown in Figure 1, will provide an indication of how long a powder will remain statically charged for after it has undergone a tribocharging event [42]. Consequently, the electrostatic properties of powders can be ranked according to their charge decay profile, from the best behaving samples (i.e. those exhibiting the lowest values for V_s , $t_{1/e}$ and $t_{10\%}$) to the worst behaving samples (i.e. those exhibiting the highest values for V_s , $t_{1/e}$ and $t_{10\%}$).

It is not always clear whether it is the excipients or API that causes failures in the manufacturing process due to punch sticking [1]. Šupuk *et al.* compared the magnitude of triboelectric charge in a number of excipients and APIs. As the excipients exhibited lower charge levels, it was hypothesised that the extent of electrostatic charging of the APIs is the predominant contributor to the electrostatic charging behaviour of pharmaceutical blends and to any related formulation issues [1]. The main drawback of the study was the lack of control of the environmental conditions. Charge decay characteristics have been shown to be susceptible to changes in relative humidity (RH) and it has been hypothesised that environmental humidity increases the amount of water adhered to the particles' surfaces, resulting in a decrease in powder resistivity [43]. Therefore, at higher RH lower electrostatic charge accumulation and faster charge decay rates are expected. For reliable measurement of the electrostatic properties of powders, triboelectric studies are recommended to be carried out under controlled RH conditions [44-48].

The aim of this study was to understand the impact of triboelectric charging on the punch sticking propensity of APIs using the JCI Chilworth 155v6 CDTA. The charge accumulation and decay of in-house Pfizer development APIs were measured under tightly controlled environmental conditions. In addition, microcrystalline cellulose (AVICEL® PH-102) and magnesium stearate were used to prepare powder blends with 10% drug loading for each of the APIs investigated. The electrostatic properties of the blends and the APIs were compared to evaluate the impact of the API on the electrostatic properties of the formulation. Furthermore, experiments were carried out to investigate the relationship between triboelectric charging and punch sticking propensity of the blends. The influence of the APIs' electrostatic properties on the sticking behaviour of the blends was also studied.

2. MATERIALS AND METHODS

2.1 Materials

A variety of Pfizer in-house development APIs (labelled as APIs 1-9) were selected for testing. Excipients used in the study included microcrystalline cellulose (AVICEL® PH-102) and magnesium stearate (Mallinckrodt, Saint Louis, MO, USA). Methanol used for cleaning was obtained from Fisher Scientific (Loughborough, UK).

2.2 Manufacture of Powder Blends

API formulations with 10% w/w drug loading were manufactured using a low shear method to produce 20 g blends. Each API (2 g) was sifted through a 850 µm mesh sieve (Endicotts Ltd, UK) into a 135 ml plastic container (Ampulla Ltd. Greater Manchester, UK), containing microcrystalline cellulose (AVICEL® PH-102) (17.95 g), followed by magnesium stearate (0.05 g). This mixture was blended for 5 min at 46 RPM using a type T2F Turbula Blender (WAB, Switzerland).

2.3 Electrostatic Characterisation

The APIs and blends were stored at 45% RH for a minimum of 24 h in a RH cabinet (Safetech Climatezone, Hampshire, UK) to allow any charge present to dissipate and for the level of moisture on the surface of the particles to equilibrate [38]. Samples were placed on the sample holder of the CDTA (JCI155 v6, Chilworth Technology Ltd. Southampton, UK) and the top of the powder bed was smoothed using a metal scraper to produce a homogeneous surface and ensure that the surface area of

powder which is exposed to the corona discharge was kept constant. The run settings for each analysis are shown in Table 1.

The electrostatic field meter of the CDTA measures the surface potential difference of the sample in Volts [49] which is directly proportional to the charge of the material [50]. Before each analysis the surface potential difference of the sample was determined to be $\leq \pm 5$ V as recommended by JCI Chilworth [49]. The corona discharge was applied to the test surface from the tips of a small cluster of fine wires mounted on the underside of a moveable plate. When the test starts, the plate retracts after charging to expose the powder surface to the field meter sensing aperture [49]. The plate speed was set to “slow” so as not to disturb the powder bed during this process. The corona discharge voltage used for all experiments was set to -8000 V. This was to simulate a powder sample becoming negatively charged when coming into contact with a metallic surface such as those typically presented by pharmaceutical processing equipment [38]. The maximum voltage which could be applied was selected in order to provide the maximum differentiation possible between each sample in terms of its charge decay characteristics. The corona discharge was applied for 0.02 s for all samples and the analysis start time began 0.07 s after the corona discharge had stopped. The temperature was controlled within the RH cabinet at 20°C for each experiment. In between measurements the sample holder was washed with methanol, rinsed with water, rinsed with methanol and allowed to dry.

The initial surface potential difference post corona charging (Vs) was recorded, as well as values for the time taken for the surface potential of the sample to decay to 1/e (36.8%) and 10% of the initial value as shown in Figure 1. Each experiment was performed in triplicate at 45% RH.

2.4 Sticking Assessment

A punch sticking assessment was performed for each API blend using a Material Adhesion Screen for Sticking (MASS) punch using previously developed methodology as described by Mullarney *et al.* [51]. Briefly, a custom F-type upper punch with removable tip and F-type lower punch (12.7 mm

diameter, round, flat face) were fitted to a single station tablet press (Manesty F3). Tablets were compressed at 3000 compressions per hour to produce 2-3mm thick tablets of 250mg mass at a solid fraction of 0.85. After 100 compressions, the tip of the upper punch was removed and weighed using a microbalance (MT5, Mettler-Toledo) to allow the mass of powder (μg) accumulated on the upper punch surface to be determined.

2.5 Data Analysis

The data recorded by the CDTA was stored in a data buffer and results were transferred to a computer via a USB port using JCI Graph software version 3.1.1 (JCI Chilworth, Southampton, UK) [49]. Subsequent analysis of the data was performed using Microsoft Excel.

3. RESULTS AND DISCUSSION

3.1 Characterisation of the Electrostatic Properties of the APIs

The initial surface potential difference and static charge decay times for each API at 45% RH are shown in Table 2 and the charge decay profiles are shown in Figure 2. By comparing the charge decay profiles and initial surface potentials, the APIs were ranked according to their electrostatic behaviour as shown in Figure 3, with the best performing having lower initial surface potentials and faster charge decay rates. API 5 had the lowest propensity to become electrostatically charged as it exhibited the lowest initial surface potential of -1092 ± 24 V and the fastest charge decay rate ($t_{10\%} = 1983 \pm 137$ s). API 4 possessed a high initial surface potential of -1809 ± 40 V, but exhibited a relatively fast charge decay rate, reaching $65.1 \pm 3.9\%$ of its initial surface potential after 9 h. This was followed by API 7, with an initial surface potential of -1241 ± 80 V and a relatively fast charge decay rate, reaching $67.9 \pm 0.7\%$ of its initial surface potential value after 9 h. Although API 6

possessed a high initial surface potential (-1650 ± 22 V), it had a relatively fast charge decay rate, reaching $70.0 \pm 0.5\%$ of its initial surface potential value after 9 h. APIs 8, 1, 2 and 9 had a relatively high propensity to become electrostatically charged due to exhibiting both high initial surface potentials (-1582 ± 39 V, -1596 ± 109 V, -1660 ± 65 V and -1691 ± 16 V, respectively) and slow charge decay rates (with $89.2 \pm 0.5\%$, $87.3 \pm 1.1\%$, $81.5 \pm 1.2\%$ and $99.0 \pm 0.2\%$ of their initial surface potentials remaining after 9 h). API 3 had the highest propensity to become electrostatically charged as it exhibited the highest initial surface potential of -1880 ± 45 V. It also possessed a very slow charge decay rate with $96.4 \pm 0.0\%$ of its initial surface potential remaining after 9 h.

3.2 Characterisation of the electrostatic properties of the blends

The initial surface potential difference and static charge decay times for each blend at 45% RH are shown in Table 3 and the charge decay profiles are shown in Figure 4. By comparing the charge decay profiles and initial surface potentials, the blends were ranked according to their electrostatic behaviour as shown in Figure 5, with the best performing having lower initial surface potentials and faster charge decay rates. As expected, the placebo blend demonstrated the lowest propensity to become electrostatically charged with the lowest initial surface potential of -657 ± 3 V and fastest charge decay rate. Blends 3, 7 and 5 with initial surface potential values of -708 ± 11 V, -765 ± 10 V and -772 ± 25 V, respectively, exhibited charge decay profiles very similar to the placebo blend. Blend 4 was next with a relatively low initial surface potential (-787 ± 9 V) and fast charge decay rate ($t_{10\%} = 11.2 \pm 0.2$ s). Blends 8, 9 and 1 were intermediate with initial surface potentials of -1014 ± 15 V, -1050 ± 10 V and -1033 ± 14 V, respectively, and $t_{10\%}$ values of 15.5 ± 0.6 s, 19.4 ± 0.8 s and 22.3 ± 0.6 s, respectively. Blends 2 and 6 exhibited the highest propensity to become electrostatically charged with the slowest charge decay rates ($t_{10\%}$ values of 32.6 ± 1.0 s and 35.6 ± 2.2 s, respectively) and initial surface potentials of -1007 ± 8 V and -997 ± 28 V, respectively.

3.3 Comparison between the Electrostatic Properties of the APIs and Blends

A notable difference was observed between the electrostatic behaviour of the APIs and the blends. The latter charged to a much lesser extent than the APIs. At 45% RH the range of initial surface potential difference of the blends was from -708 ± 11 V to -1050 ± 10 V, whereas, the range of initial surface potential of APIs was from -1092 ± 24 V to -1880 ± 45 V. In addition, the charge decay rates of the blends were much faster than their corresponding APIs. The $t_{10\%}$ values reported for the blends ranged from 6.9 ± 0.1 to 35.6 ± 2.2 s compared to this value not being reached for the APIs, with the exception of API 5 ($t_{10\%} = 1983 \pm 137$ s).

The electrostatic behaviour of the APIs was significantly improved by formulation in powders containing microcrystalline cellulose (AVICEL® PH-102) and magnesium stearate. These results were in good agreement with reports available in the literature. Engers *et al.*, studied the surface charge density for binary mixtures of common pharmaceutical materials and reported that for mixtures containing microcrystalline cellulose, the surface charge density was effectively reduced with respect to the values of the pure components [52]. The addition of magnesium stearate was shown to have a negligible effect on the electrostatic behaviour of the blends despite its very poor electrostatic behaviour (high Vs and slow charge decay rates) observed in this study and considerably higher resistivity compared to other excipients, reported by Grosvenor *et al.* [53]. The same study also demonstrated that the addition of magnesium stearate to lactose and microcrystalline cellulose at low concentrations (0.5% w/w) had a negligible effect on their resistivity. However, at 3% w/w concentration in DCP, the resistivity increased by 500 fold at 0% RH and 150 fold at 66% RH [53]. This effect may have been observed because conduction is assumed to occur across particle surfaces rather than through them [53]. At low concentrations of magnesium stearate, sufficient lactose and microcrystalline cellulose inter-particle contact points existed to form continuous conduction pathways across surfaces devoid of the lubricant. In the dibasic calcium phosphate formulation, the resistivity increased as the surface coverage was greater [53].

Despite the formulations in the current study significantly damping the effect of API, its impact on the electrostatic properties and punch sticking propensity of the formulation should not be disregarded. There is a difference between the charge decay profile of the placebo and each API blend (Figure 4), with the V_s , $t_{1/e}$ and $t_{10\%}$ values of the placebo blend being notably lower than each API blend (Table 3). Moreover, the punch sticking propensity of the placebo blend is clearly lower than all of the API blends, with the exception of API 5 blend where it was equivalent.

Interestingly, a change in the rank order was observed between the blends and APIs. Formulation as a blend changed the classification of API 3 from a high charging to a low charging category. The opposite trend was observed for API 6. This phenomenon may be due to the ordering of particles within the blend structure [36, 54]. Since API 3 was the only compound that does not form agglomerates (data not presented), it may be hypothesised that blending resulted in the formation of a homogenous mixture, providing sufficient API 3 and microcrystalline cellulose inter-particle contact points, resulting in effective charge reduction and lower sticking propensity than would be predicted based on measurement of the API alone.

3.4 Relationship between Electrostatic Properties and Sticking Propensity

The relationships between initial surface potential and sticking propensity for the blends and APIs are shown in Figure 6 A and B, respectively. Particle surface area has been shown to have an effect on sticking, with most authors reporting an increase in sticking propensity as surface area increases [36, 55]. Moreover, a linear correlation ($R^2 = 0.81-0.98$) between triboelectric charging and surface adhesion observed by Ghori *et al.* was shown to be highly dependent on particle size and surface area. A reduction in the correlation was observed with decreasing particle size [36]. The large surface area associated with fine particles was suggested to increase the number of particle and surface contacts thereby increasing their sticking tendency [56]. API 1 was prepared by micronisation whereas the other API samples were milled, it may thus be hypothesised that its sticking propensity was also

highly affected by its surface area. Hence, “API 1 blend” and “API 1” were considered to be outliers and the graphs were replotted in the absence of these samples as shown in Figure 6 C and D. This resulted in a better correlation between particle punch sticking and initial surface voltage of the blends compared to the APIs with correlation coefficients of 0.58 and 0.18, respectively. The significant reduction in the charging propensity of the APIs in the formulated blends may account for this poor correlation. Nevertheless, the main contributors to the electrostatic behaviour of the blends were the APIs.

A reduction in sticking was observed with an increase in charge dissipation rate. The relationship between $t_{1/e}$ and $t_{10\%}$ with punch sticking propensity for the blends is shown in Figure 7 A and B respectively. Reduction in the susceptibility of the blend to retain electrostatic charge was proportional to sticking propensity, with correlation coefficients of 0.89 and 0.88, respectively. These data show that, the propensity for sticking may therefore be better predicted by the longevity of charge retained on the surfaces of the particles than the magnitude of the charge acquired.

3.5 Further Work

Further work could look to expand on the investigations described in this study by using the CDTA to determine how properties such as particle size, morphology, chemical structure, surface area and surface energy contribute to the electrostatic properties of pharmaceutical powders. The electrostatic properties of pharmaceutical powder formulations are known to be highly dependent on RH. As such, punch sticking assessments should be performed under controlled environmental conditions, which was not possible in the current study. Considering that, as the RH increases, the capillary force increases and contributes to an increase in sticking [38]. Further experiments should investigate punch sticking at a range of relative humidities in order to investigate the relative contributions of both electrostatic and capillary forces to the sticking propensity of pharmaceutical blends.

4. Conclusions

APIs may become electrostatically charged to a higher extent than tableting excipients. Despite the excipients significantly damping the charging propensity of the API in a powder formulation, the electrostatic behaviour and punch sticking propensity of the majority of the formulated blends were dominated by the API, even at only 10% w/w loading. This study revealed that the electrostatic charge decay rates of powders may significantly impact their punch sticking propensity. Consequently, this work contributes to the understanding of how problems may arise in formulation, processing and manufacture of pharmaceutical dosage forms due to electrostatic charge accumulation. The selection of powders with fast charge decay kinetics and a tight control of environmental conditions may help to mitigate punch sticking problems during tablet production. Further studies aimed at deconvoluting the relative contribution of particle physico-chemical properties to bulk powder electrostatic behaviour and sticking propensity would be advantageous.

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ABSTRACT

Purpose The present study details characterisation of the electrostatic properties of a range of active pharmaceutical ingredients (APIs) and blends and investigates the role of electrostatics as a potential root cause of punch sticking during tableting.

Methods Microcrystalline cellulose (AVICEL® PH-102) and magnesium stearate were used to prepare blends of constant drug loading (10% w/w) with a range of APIs. The electrostatic properties of the APIs and blends were then determined using a JCI Chilworth 155v6 Charge Decay Time Analyser (CDTA) under controlled environmental conditions. The measurements recorded were then correlated to a punch sticking assessment of each blend, which was obtained utilising a Material Adhesion Screen for Sticking (MASS) Punch.

Results The APIs became electrostatically charged to a higher extent than the blends. The linear relationship between particle punch sticking and the maximum surface voltage (V_s) attained post charging was poor ($R^2 = 0.58$). However, a reduction in the susceptibility of the blend to retain electrostatic charge, as determined by the measurement of charge decay times (Time 1/e and Time 10%), was found to be linearly proportional ($R^2 = 0.89$ and 0.88 respectively) to the sticking propensity.

Conclusion Despite the excipients significantly damping the charging propensity of the API in a formulation, the electrostatic behaviour and punch sticking propensity of the majority of the formulated blends were shown to be dominated by the API (even at only 10% w/w). It is anticipated that the use of formulations with fast charge decay rates may reduce sticking problems during tablet production.

KEY WORDS Triboelectrification, electrostatic charge, sticking, direct compression

Figure 1. Typical surface potential verses time decay profile generated with a Charge Decay Time Analyser (CDTA). This figure has been adopted from [38].

Figure 2. Charge decay profiles for the APIs at 45% RH and 20°C.

Figure 3. Ranking of electrostatic behaviour of the APIs according to initial surface potential

Figure 4. Charge decay profiles the placebo and active blends at 20°C, 45% RH

Figure 5. Ranking of electrostatic behaviour of the blends according to initial surface potential

A

B

C

D

Figure 6 Initial surface potential (V) plotted as a function of adhesion to the Material Adhesion Screen for Sticking punch (μg) for A the placebo and API blends, B, the APIs, C the blends with the exception of API blend 1 and D the APIs with the exception of API 1 (n=3, mean ± SD)

Figure 7 Static charge decay times of the blends plotted as a function of adhesion to the Material Adhesion Screen for Stickingpunch (μg) ($n=3$, mean $\pm$ SD).

A and B show the full data sets for Time 1/e and Time 10% respectively. C and D show the same data replotted without the values from API 1 blend.

Table 1. Settings of the JCI155 v6 Charge Decay Time Analyser (CDTA) used for electrostatic charge decay measurements.

Run Settings	
Pretest Voltage (V)	$\leq \pm 5$
Corona Voltage (V)	8000
Corona Time (s)	0.02
Analysis Start (s)	0.07
Plate Speed	Slow
Temperature (°C)	20

Table 2. Initial surface voltage (Vs), times from Vs to 1/e and 10% of this value and amount of charge remaining on the sample after 9 h (as a percentage of initial surface potential) for the APIs at 45% relative humidity (RH) and temperature = 20°C (n = 3, mean $\pm$ SD).

API	Vs (V)	Time 1/e (s)	Time 10% (s)	Charge remaining after 9 h (% of Vs)
API 1	-1596 $\pm$ 109	N/R ^a	N/R	87.3 $\pm$ 1.1
API 2	-1660 $\pm$ 65	N/R	N/R	81.5 $\pm$ 1.2
API 3	-1880 $\pm$ 45	N/R	N/R	96.4 $\pm$ 0.0
API 4	-1809 $\pm$ 40	N/R	N/R	65.1 $\pm$ 3.9
API 5	-1092 $\pm$ 24	130 $\pm$ 13	1983 $\pm$ 137	0.0 $\pm$ 0.0
API 6	-1650 $\pm$ 22	N/R	N/R	70.0 $\pm$ 0.5
API 7	-1241 $\pm$ 80	N/R	N/R	67.9 $\pm$ 0.7
API 8	-1582 $\pm$ 39	N/R	N/R	89.2 $\pm$ 0.5
API 9	-1691 $\pm$ 16	N/R	N/R	99.0 $\pm$ 0.2

^a Not Reached

Table 3 Initial surface voltage (Vs), time 1/e, time 10% and punch sticking values for the blends at 20°C, 45% RH (n = 3, mean $\pm$ SD).

Blend	Initial surface potential difference (V)	Time 1/e (s)	Time 10% (s)	MASS punch adhesion (μ g)
Placebo	-657 $\pm$ 3	1.7 $\pm$ 0.1	5.3 $\pm$ 0.1	0
API 1	-1033 $\pm$ 14	4.7 $\pm$ 0.1	22.3 $\pm$ 0.6	2065
API 2	-1007 $\pm$ 8	4.6 $\pm$ 0.1	32.6 $\pm$ 1.0	524.5
API 3	-708 $\pm$ 11	1.9 $\pm$ 0.0	6.6 $\pm$ 0.1	27.5
API 4	-787 $\pm$ 9	2.5 $\pm$ 0.0	11.2 $\pm$ 0.2	356
API 5	-772 $\pm$ 25	2.0 $\pm$ 0.1	6.7 $\pm$ 0.2	0
API 6	-997 $\pm$ 28	5.3 $\pm$ 0.2	35.6 $\pm$ 2.2	683
API 7	-765 $\pm$ 10	2.1 $\pm$ 0.0	6.9 $\pm$ 0.1	78
API 8	-1014 $\pm$ 15	3.5 $\pm$ 0.1	15.5 $\pm$ 0.6	304
API 9	-1050 $\pm$ 10	3.6 $\pm$ 0.2	19.4 $\pm$ 0.8	282

Graphical abstract

Highlights

The electrostatic properties of several simple direct compression blends were characterised

The electrostatic properties of the blends were dominated by the API, even at low drug loading

A linear relationship was found between charge decay rate and adhesion to compression tooling