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Influence of the morphogranulometry and hydrophobicity of talc on its antisticking power in the production of tablets

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Abstract

Antisticking power varies according to the talc considered. It is difficult to define the physical properties of talc implicated in its antisticking power. In this work, different talcs were characterized and an evaluation made of their performance in reducing sticking in tablet manufacturing. Determination of the specific surface area was made by permeametry, morphogranulometric analysis by laser diffractometry using a method, which made it possible to assess the mean thickness of talc particles, and measurement of water absorption kinetics was taken to assess hydrophobicity. The relationship between the characteristics of talcs and their antisticking power was then considered. There is a correlation between the particle size of talc and surface hydrophobicity. The detaching force of tablets appears to be dependent on the basal dimension of talc.
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1. Introduction

The mix of powders from which a tablet is made includes an active ingredient and several excipient; the latter are included to improve the compression parameters of the tablet and the bioavailability (Ribet et al., 2003). Talc is usually added as an antisticking agent. The necessary quality of the excipients dictates a chemical control described in the European Pharmacopoeia if a monography exists, but as this is not sufficient, the suitability of the excipient for use must be assessed by functionality assays. As these assays are difficult to apply, the European Pharmacopoeia proposes defining for a given material the physical properties relating to functionality and their analysing methods.

At present, the European Pharmacopoeia monography defines talc only by its chemical characteristics: "it

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is a selected and pulverized native hydrous magnesium silicate with a chemical structure [$Mg_3Si_4O_{10}(OH)_2$] (European Pharmacopoeia, 2002). It sometimes contains variable quantities of associated minerals including mainly chlorites (hydrous magnesium and aluminium silicates), magnesite (magnesium carbonate), calcite (calcium carbonate) and dolomite (calcium and magnesium carbonate)". Talc is defined as a crystalline structure characteristic of lamellar structures. It has been shown that according to the source and method of preparation, the chemical composition of talc varies, in particular the presence of impurities like calcium carbonate, calcium silicate and iron oxide. These impurities result in modification of the physical characteristics of the talc (Gold and Campbell, 1964). As it is difficult to define very precisely the physical properties linked to its antisticking power, according to the preparation method used, the antisticking power of talc could vary.

The antisticking power could be dependent on morphogranulometric characteristics and/or surface properties. The characterization of the surface properties and especially the surface-free energy of the solids are recognized as the key to understanding the mechanism of surface-based phenomena (Yildirim, 2001). The standard approach used for determining the surface-free energies of solids and the interfacial surface-free energies between interacting surfaces has been through wetting experiments. Specifically, the contact angle method has been widely used to characterize the surface properties of solids especially when measuring surface hydrophobicity. Contact angle measurements are easy to obtain on a smooth flat surface, and there are several well-known techniques for measuring the contact angles of liquids on flat surfaces. In many industrial applications, however, materials are used in powdered form. In such a case, it becomes more difficult to obtain the value of the contact angle for powdered surfaces. Even if wicking technique could be used, it could be interesting to have alternative techniques available to measure talc surface properties, particularly hydrophobicity.

The aim of this study was to investigate the morphogranulometry and hydrophobicity of talc particles and to determine if there was a correlation between the two parameters. To this end, we used a simple method to assess talc hydrophobicity by measuring the kinetics of water absorption of a powder bed.

In a previous work (Flament et al., 2002), we studied the antisticking power of different talcs. We characterized them and compared talcs before and after delamination, which is a way to obtain talcs with different physical characteristics.

We wanted to consider the relationship between the characteristics of talcs and their antisticking power but it was difficult to fully explain variations between talcs. In this work, we particularly studied the morphogranulometry and the hydrophobicity of different talcs and the relationship between these characteristics of talcs and their antisticking power was then considered.

2. Materials and methods

2.1. Materials

A talc of pharmaceutical quality (talc 1), from which different samples were obtained by delamination and/or granulometric classification. For this purpose, a dynamic air classifier, Hosokawa-Alpine 50 ATP, was used. Three products were obtained after classification (Baudet et al., 1998):

- product *X*.1 collected from the filter,
- product *X*.2 collected from the cyclone, and
- product *X*.3 collected from the turbine.

With $X = 1$ in the case of direct classification of talc and $X = 2$ when talc 1 was classified after delamination. Fig. 1 shows the different types of talc obtained after these procedures.

The samples used are identical with those used in the previous paper (Flament et al., 2002).

2.2. Methods

2.2.1. Determination of the specific surface area by permeametry

We used a Fisher sub-sieve-sizer apparatus, which measures the mean size of powder particles. The measuring principle is based on the laws of permeametry, that is to say the flow capacity of a fluid (air) through a bed of powder with a set porosity. Permeametry allows the specific surface to be calculated, defined as the particle-specific surface area per unit volume. This volume is the volume of the particles without external pores (Merle et al., 1979).

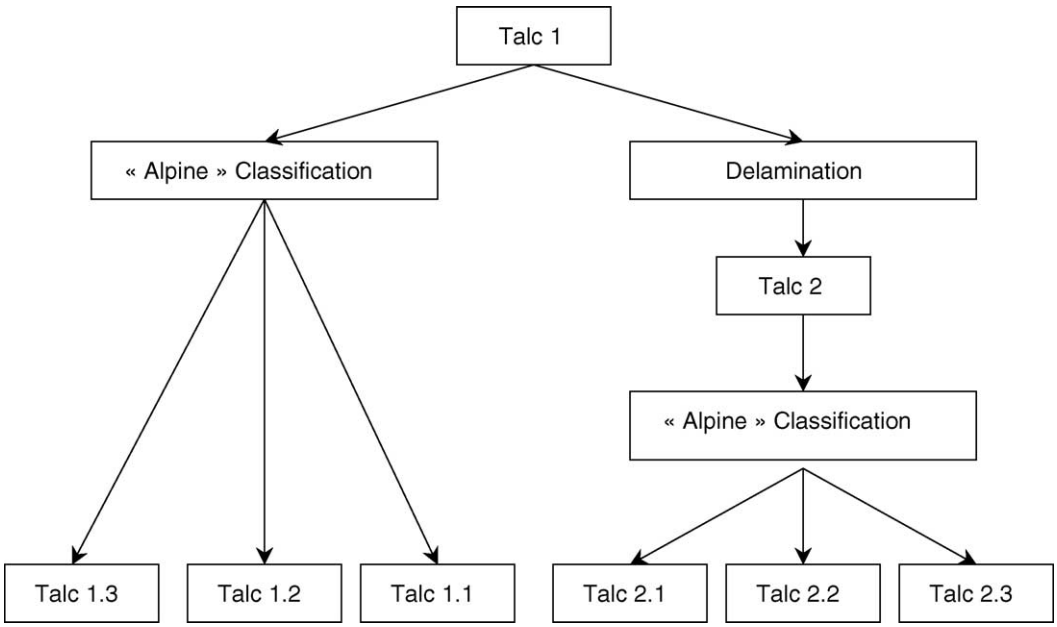

Fig. 1. Diagram of talc treatment.

The volume surface mean diameter can be read directly on a calculator chart located on the apparatus using a sample weight equal to the true density of the materials that is to say 2.71 g/cm^3 in the case of talc. Samples have been used as received.

The sample weight is introduced into the compression tube of the apparatus between two filters and compacted with moderate pressure so that a uniform porosity is achieved. Dry compressed air is passed through the tube and the air pressure measured with a water manometer. The porosity and the diameter are read directly on the calculator chart. We repeat the porosity readings at successively higher degrees of compaction until the diameter reaches a minimum value. This procedure is described in the monography "Griseofulvin" of the USP (USP, 2003).

The mean particle diameter may be expressed in terms of area per unit volume (Sv, m^2/cm^3) or in terms of area per unit mass (Sm, m^2/g). All the measurements were performed in triplicate.

2.2.2. Morphogranulometric analysis

This was carried out by laser diffractometry with a Malvern Mastersizer S laser size analyser, using the Fraunhofer theory. Measurements were made on very diluted aqueous suspensions (0.06–0.23 g/l according to talc granulometry) with laminar flow through the fine cell (0.5 mm) under analysis. This type of flow favours selective orientation of the lamellar particles as they present their basal surfaces perpendicularly to the laser beam.

Under these conditions, measurements make it possible to determine (Baudet et al., 1993):

- the projected area distribution of particles with
  - dmL: mean basal surface diameter
  - d99L: projected area diameter corresponding to 99% of cumulative undersize and
- the mean thickness *h* of the lamellar particles, which is obtained by the ratio of their specific volume to their specific projected area.

The mean shape factor or mean geometric aspect ratio (AR) is defined as AR = dmL/*h*.

2.2.3. Measurement of the kinetics of water absorption of a powder bed

This assay consists in measuring on the one hand the quantity of water absorbed by a sample of talc and on the other hand the absorption kinetics.

We used the measurement system of Ringard et al. inspired from that of Nagami (Ringard et al., 1977). A

horizontal tube graduated in 1/100^{e} ml is connected to an Allin tube whose sintered glass (porosity 3) is on the same horizontal level as the graduated tube. Water is introduced into the horizontal tube to reach the upper surface of the sintered glass.

0.25 g of talc is deposited on the sintered glass and a chronometer started. The visualisation of the total wetting of the powder is made easier by putting some particles of methylene blue on the upper surface of the powder bed (talc).

Dissolution of methylene blue shows the end of the experiment. The volume of absorbed water and absorption time are noted.

2.2.4. Assessment of antisticking power of talc in relation to Avicel PH 102

In a previous work, a functionality assay was defined on a single punch press to assess the antisticking power of talcs (Flament et al., 2002). The assays were performed on a Frogerais OA single punch press where the feed shoe was set up to measure the force required to detach the tablet from the lower punch surface. The transducer was calibrated so that 1 mV squared with 10^{-1}N. Measurement precision was 1%. The assays were performed with blends of Avicel PH 102 and 1% talc.

2.2.5. Statistical data evaluation

The statistical analysis of the data was obtained through a one-way analysis of variance.

3. Results and discussion

Table 1 presents the results of mean particle diameter and specific surface area determined by permeametry for the different talcs. These two characteristics differ significantly for all the talcs studied (ANOVA, $P < 0.001$).

Comparison of talcs 1 and 2 indicates that after delamination the mean diameter decreases and specific surface area increases. The same remarks can be made after comparing the different granulometric fractions before and after delamination: fractions 1.3, 1.2 and 1.1, respectively, compared to fractions 2.3, 2.2 and 2.1.

Surface increase after delamination is due to the creation of new lamellae by decreasing particle thickness. However, measurements by permeametry alone do not make possible to affirm that the decrease in mean diameter does not come from a decrease in the basal dimension because of a particle breaking during delamination. To check this, a morphogranulometric analysis is carried out with a laser granulometer in conditions that make it possible to assess the basal dimension (dmL) and the thickness (h) of the particle (Table 2). The results are significantly different for all the talcs studied (ANOVA, $P < 0.001$).

Modifications in the mean morphology of particles caused by delamination lead to a significant decrease in the mean thickness h of lamellae and to an increase in the mean geometric aspect ration AR of talc 2 when compared to the initial talc 1. But, the dmL and the d99L vary little.

In the same way, comparison of the granulometric fractions 1.3, 1.2 and 1.1, respectively, with fractions 2.3, 2.2 and 2.1 indicates that the dmL varies little after delamination, which confirms that comminution of lamellae in directions parallel to basal faces (delamination) is more active than comminution in normal directions (breakage of lamellae). As regards the thickness of lamellae, it decreases strongly after delamination

Table 1
Average particle size, area per unit volume and area per unit mass of the different talcs assessed by permeametry (mean of three replicates ± S.D.)

Talc	Porosity of the powder bed	Mean particle diameter (μm)	Sv (area per unit volume) (m^2/cm^3)	Sm (area per unit mass) (m^2/g)
1	0.42	2.2 (±0.05)	2.727 (±0.068)	1.006 (±0.0024)
1.1	0.45	0.9 (±0.02)	6.666 (±0.22)	2.460 (±0.083)
1.2	0.4	2.3 (±0.05)	2.608 (±0.068)	0.963 (±0.024)
1.3	0.42	5.7 (±0.11)	1.052 (±0.021)	0.388 (±0.0075)
2	0.5	0.7 (±0.0006)	8.571 (±0.069)	3.163 (±0.025)
2.1	0.5	0.6 (±0.0006)	10.000 (±0.092)	3.690 (±0.034)
2.2	0.45	1.4 (±0.028)	4.285 (±0.091)	1.581 (±0.034)
2.3	0.4	3.2 (±0.05)	1.875 (±0.033)	0.692 (±0.012)

Table 2
Granulometric results of the different talcs assessed with laser size analysis (mean of three replicates ± S.D.)

Talc	d99L (μm)	dmL (μm)	*h* (μm)	A.R.
1	68.71 (±0.75)	12.16 (±0.07)	0.56 (±0.03)	21.64 (±1.32)
1.1	9.49 (±0.08)	2.13 (±0.01)	0.11 (±0.01)	19.02 (±0.05)
1.2	18.07 (±0.15)	4.52 (±0.02)	0.26 (±0.01)	17.52 (±0.08)
1.3	66.04 (±0.47)	13.33 (±0.08)	1.70 (±0.05)	7.84 (±0.05)
2	53.22 (±0.47)	10.45 (±0.06)	0.29 (±0.01)	35.91 (±0.95)
2.1	10.76 (±0.07)	2.23 (±0.01)	0.12 (±0.01)	18.74 (±0.29)
2.2	17.81 (±0.11)	4.84 (±0.02)	0.23 (±0.001)	20.68 (±0.06)
2.3	56.15 (±0.76)	15.15 (±0.07)	0.78 (±0.04)	19.42 (±0.47)

for the 1.3 fraction (compared to 2.3 fraction) but varies little for the 1.2 and 1.1 fractions (compared to 2.2 and 2.1 fractions, respectively). Delamination is effective only for the thickest talc particles and no longer operates when thickness is in the order of 0.25 μm.

Table 3 presents the results of water absorption for the different talcs. The absorption time and the absorbed volume are significantly different for the different talcs (ANOVA, $P < 0.001$). The quantities of absorbed water are very low, which confirms the hydrophobic character of the different talcs.

Comparison of behaviour of the granulometric fractions before and after delamination makes it possible to determine three groups:

- Talcs 1.1 and 2.1 that do not absorb at all. These talcs present the smallest dmL and thickness and the highest specific surface.
- Talcs 1.3 and 2.3 with the highest dmL and thickness quickly absorb a quantity of water that remains low. These talcs present the smallest specific surface.
- Talcs 1.2 and 2.2 that have an intermediate behaviour between the two previous groups. Their dmL, thickness and specific surface are also intermediate. However, the absorption time of talc 2.2, which is delaminated, is higher than that of talc 1.2.

Table 3
Characteristics of water absorption by the different talcs (mean of three replicates ± S.D.)

Talc	Absorption time (min)	Absorbed volume (ml)
1	6 (±0.57)	0.08 (±0.006)
1.1	Infinite (>120)	0
1.2	35 (±3)	0.02 (±0.005)
1.3	6 (±0.5)	0.05 (±0.005)
2	8 (±0.57)	0.10 (±0.006)
2.1	Infinite (>120)	0
2.2	65 (±1.5)	0.03 (±0.005)
2.3	8 (±0.57)	0.05 (±0.005)

The results of talcs 1 and 2 are more difficult to explain because they are the blends of different granulometric fractions. However, for these two talcs, behaviour is close to that of their granulometric fraction whose dmL is the highest (1.3 for talc 1, and 2.3 for talc 2). This fraction influences blend behaviour.

The results of measurements of tablet detaching force compared to functioning time of the tablet machine are summarised in Table 4. Whatever the functioning time, the tablet detaching forces for the different samples of talcs differ significantly (ANOVA, $P < 0.001$).

Looking at the data, three groups of talcs are significant:

- The first group consists of talcs 1.1 and 2.1 for which there is no sticking. Their d99L and dmL values are the lowest: about 10 and 2 μm, respectively.
- A second group made up of talcs 1.2 and 2.2 for which detaching values are lower than those obtained with other talcs. Their d99L and dmL are close to 18 and 4.5 μm, respectively.
- The third group made up of the other talcs (1, 2, 1.3 and 2.3). They present more pronounced sticking that cannot be distinguished. The d99L and dmL values are higher: around 60 and 12 μm, respectively.

The detaching force of tablets appears to be dependent on the mean basal dimension of lamellae. The required detaching force increases with dmL.

The results indicate that the best reductions in sticking are obtained when using the finest talcs. These talcs are also those whose hydrophobicity is the highest.

Table 4
Unsticking force of tablets containing Avicel PH 102 associated with different samples of 1% talc, at different functioning times of the tablet press (mean of five replicates ± S.D.)

Sample	Unsticking force (N) after 0.5 min	Unsticking force after 1 min (N)	Unsticking force after 3 min (N)	Unsticking force after 4.5 min (N)	Unsticking force after 5 min (N)
Avicel PH 102 alone + 1% talc:	59.00 (±0.75)	73.47 (±4.0)	114.1 (±2.5)	114.1 (±2.8)	131.75 (±1.8)
1	97.27 (±3.16)	103.20 (±3.2)	103.46(±1.24)	104.22 (±3.4)	104.47 (±3.1)
1.1	0	0	0	0	0
1.2	52.27 (±2.2)	48.38 (±1.35)	44.86 (±1.06)	49.86 (±2.4)	46.98 (±1.64)
1.3	72.84 (±2.54)	85.10 (±3.18)	89.54(±2.0)	91.06 (±1.04)	99.83 (±1.60)
2	64.88 (±2.1)	66.68 (±1.6)	76.54(±2.45)	77.70 (±3.5)	70.88 (±2.64)
2.1	0	0	0	0	0
2.2	34.30 (±1.36)	29.07 (±1.31)	29.18(±0.54)	27.30 (±1.2)	19.68 (±0.65)
2.3	71.60 (±3.1)	71.60 (±3.1)	135.80(±5.0)	134.90 (+/2.75)	138.80 (±5.11)

Our results on hydrophobicity concord with previous studies relating to talc. For example, Yildirim found a strong correlation between surface hydrophobicity and the particle size of talc. The finer particles exhibited higher values of water contact angles, and hence lower values of total surface-free energy compared to those of larger particles (Yildirim, 2001). Surface-free energy characterization of basal and edge surfaces of talc by flow microcalorimetry gave the same results: talc powders of smaller particle size showed higher surface hydrophobicity, i.e., a lower percentage of hydrophilic surface, compared to those of larger particle size. In the same way, Wu et al. (1996) studied the effect of pulverization on the surface properties of minerals and found that the surface of minerals became more hydrophobic with grinding.

In fact, particles of talc have the shape of platelets due to the layer structure of the mineral and the basal surfaces are hydrophobic while the edge surfaces are hydrophilic (Good and Van Oss, 1992; Janczuk et al., 1993). The hydrophobicity of the basal surfaces is due to the fact that the atoms exposed on the surface are linked together by siloxane (Si–O–Si) bonds and, hence, do not form strong hydrogen bonds with water. The edge surfaces, on the other hand, are composed of hydroxyl ions, magnesium, and silicon and substituted cations all of which undergo hydrolysis. As a result, the edges are hydrophilic, and they can form strong hydrogen bonds with water molecules and polar substance (Padday, 1978; Yariv, 1992; Zisman, 1977).

In our study, talc hydrophobicity increases after delamination. In fact, delamination induces a decrease in the size of the hydrophilic edge surface and the creation of new hydrophobic basal surfaces. The dmL parameter seems to be more influent on the antisticking power than the specific surface.

It seems that the increase in hydrophobicity could be favourable to the antisticking power of talc. Indeed, the most hydrophobic talcs present a lower surface-free energy that could decrease the adhesion work of talc on the surface of the press punches and so decrease the force required to eject the tablets.

4. Conclusion

Delamination and granulometric classification make it possible to obtain talcs with different physical characteristics. After delamination, the specific surface increases because of the creation of new lamellae by decreasing particle thickness, but the basal dimension varies little. There is a correlation between the particle size of talc and surface hydrophobicity.

The different talcs tested possess considerable variations in antisticking power towards Avicel PH 102. The required detaching force of tablets increases with the mean basal dimension of talc. The best reductions in sticking are obtained when using the finest talcs whose hydrophobicity is the greatest.

The suitability of talc for use can be assessed by a functionality assay, which requires an instrumented single punch press and feed shoe. The mean basal dimension of talc particles measured by laser diffractometry and the measurement of the kinetics of water absorption could be used to forecast antisticking power. These tests could be added to suppliers' specifications and could be used as functionality assays.

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