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Distribution of magnesium stearate on the surface of lubricated particles

L. Roblot-Treupel and F. Puisieux
Laboratoire de Pharmacie Galénique et de Biopharmacie, J.E. CNRS 4848, 92296 Châtenay-Malabry (France)

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Summary

The distribution of magnesium stearate on the surface of granules is investigated using the scanning electron microscope and microanalysis. The results confirm the preferential location of the stearate in the cavities, and the regularization of the surface provided by the lubricant. Microanalysis of magnesium stearate indicates that a maximum fixation capacity exists.

Introduction

A relatively large number of investigations have been devoted to the study of lubricant distribution on the surface of lubricated particles. Most of them were carried out with magnesium stearate and three main possibilities were pointed out. Some authors (Bolhuis et al., 1975) chose for the formation of a *monomolecular film*. The lubrication, in this case, is of the interfacial type. The interparticle surfaces are only separated from each other by a few molecules of stearate. Friction effects, depending not only on the properties of the lubricant but also of the underlying surfaces, are relatively numerous. Several studies (Tawashi, 1963a and b) concluded in the formation of a *uniform continuous layer of the monoparticulate type.* In this case, lubrication by stearate is of the *fluid or hydrodynamic* type. The interparticulate surfaces are separated from each other by a relatively thick and continuous coat of lubricant. Friction effects, related exclusively to the resistance to movement of the lubricant itself, are normally weak. A number of authors (List and Müller, 1972; Bolhuis et al., 1980) chose for the *progressive filling of the cavities* of the material to be lubricated by lubricant particles, so that the effect of the stearate would be associated with the equalization of the surfaces. By acting in this way, the lubricant diminishes the contact points and reduces interparticle friction. Pintye-Hodi et al. (1981) attempted to locate the magnesium stearate on the surface of micronized particles, using a microanalyzer. These authors chose for a non-uniform distribution of the stearate on the particle surfaces.

The results reported here followed previous studies which consisted of the investigation of the compression characteristics and the properties of the tablets obtained from differently lubricated granules (Roblot et al., 1980, 1983a and b). For a

Correspondence: L. Roblot-Treupel, Laboratoire de Pharmacie Galénique et de Biopharmacie, J.E. CNRS 4848, 5 rue Jean-Baptiste Clément, 92296 Châtenay-Malabry, France.

better understanding of the lubricant distribution mode, a scanning electron microscope study was undertaken, together with the determination of magnesium stearate on the granule surfaces by microanalysis.

Materials and Methods

The *lubricant* used during this study was a heavy magnesium stearate (Ph. Fr. IX Ed.). The *lubrication support* consisted of inert sorted granules (800–1000 μm) with substantially smooth surfaces (Fig. 1). The granules were mixed with magnesium in a Turbula mixer (Prolabo, Paris) for 5 min.

The *microscope examination* was carried out using a scanner electron microscope (Philips Type 505, Bobigny). It was carried out both on whole granules and granule sections. In the latter case, the granules were coated in a mecaprex resin.

Local microanalysis of magnesium was performed using a Link microanalyzer equipped with an Si(Li) detector for detection from carbon.

Total microanalysis of magnesium stearate really fixed on the granules was performed using an inductive type argon plasma emission spectrometer (Jobin and Yvon). The temperature in the argon plasma was 5500°C. The magnesium line was at 2852 Å. The samples were treated with hydrochloric acid and then mineralized at 500°C for 16 h.

Results

Fig. 2 shows the granule lubricated by 2% magnesium stearate and magnified only 100 times. Even at this low magnification, it appears that the lubricant is distributed non-uniformly on the granule surface, and appears to lodge preferentially in the cavities.

Fig. 3 shows a given area of the same granule magnified 600 times. The photograph confirms the

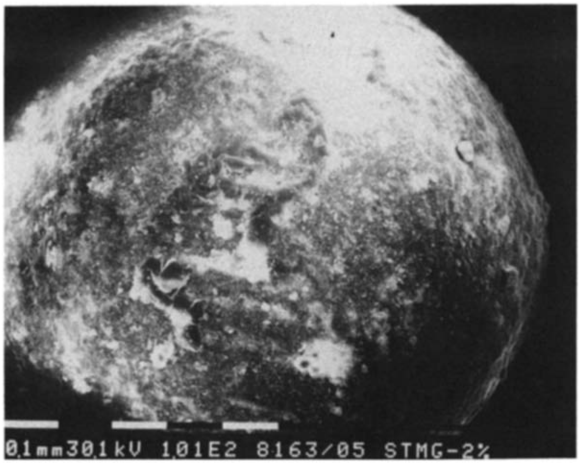

Fig. 2. Granule lubricated by 2% magnesium stearate. ×80.

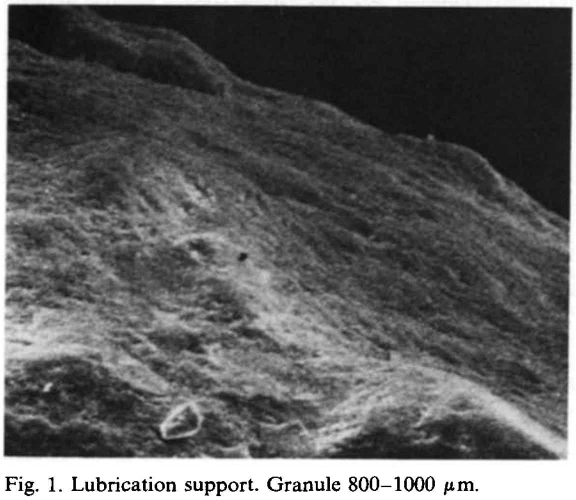

Fig. 1. Lubrication support. Granule 800–1000 μm.

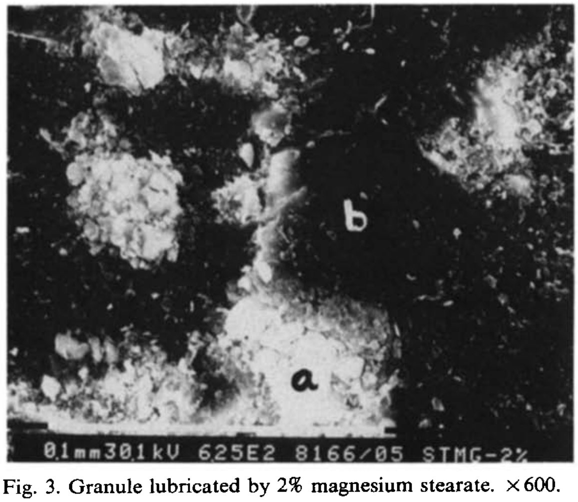

Fig. 3. Granule lubricated by 2% magnesium stearate. ×600.

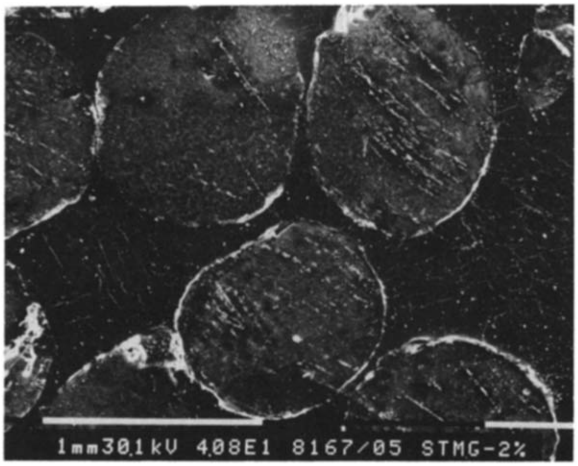

Fig. 4. Section of granule lubricated by 2% magnesium stearate. ×40.

non-uniform distribution. It shows a very lubricated zone (white area) probably corresponding to a cavity, and areas not covered by magnesium stearate (dark areas) probably corresponding to projections.

Granule sections were prepared for a better anlaysis of the magnesium stearate distribution on the surface. Fig. 4 was taken with a magnification of 40. It clearly confirms the preferential location of the stearate in the cavities, and also the regularization of the surface provided by the lubricant.

Fig. 5 was taken with a magnification of 300. It confirms the foregoing observations even more clearly.

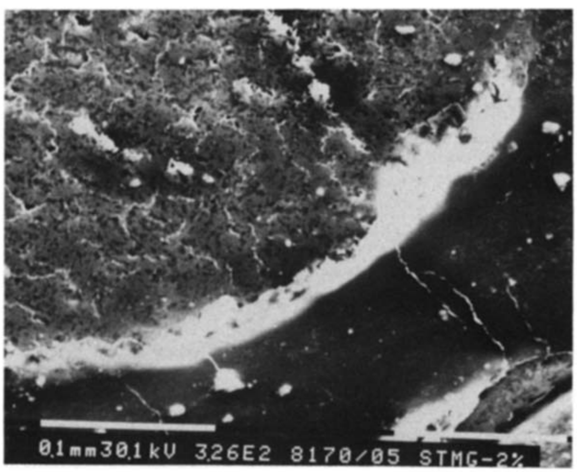

Fig. 5. Section of granule lubricated by 2% magnesium stearate. ×300.

Local microanalysis of magnesium (Fig. 6) reveals a very high magnesium peak in the magnesium stearate-rich areas (a) and a practically non-existent peak in the sterate-poor areas (b).

Total microanalysis of magnesium stearate really fixed on the granules serves to note a number of interesting points (Table 1). When the stearate rate is approximately 0.25%, all the stearate is found on the granules (0.24%). However, if the

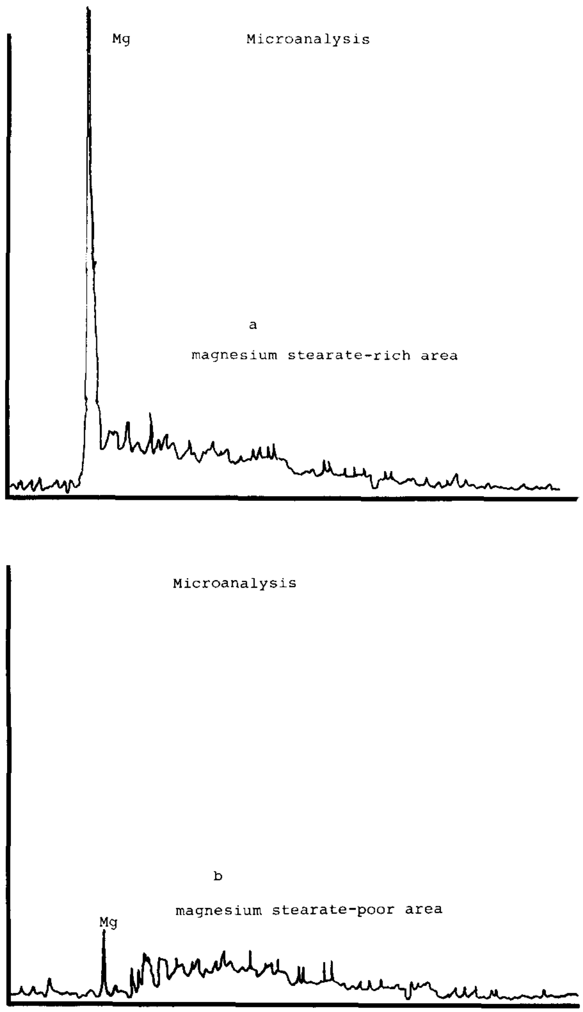

Fig. 6. Local microanalysis of magnesium on granule lubricated by 2% magnesium stearate. a: magnesium stearate-rich area. b: magnesium stearate-poor area.

TABLE 1

TOTAL MICROANALYSIS OF MAGNESIUM STEARATE REALLY FIXED ON THE GRANULES

Stearate rate (%)	Stearate found on the granules (%)
0.25	0.24
1.5	1.00
2.0	1.40

percentage added is greater than 0.25%, the amount really fixed is much smaller. Hence, for 1.5% it is about 1% and for 2% it is only 1.4%. Hence it appears that a maximum fixation capacity exists, which is approached as the quantity of lubricant added is progressively increased.

Discussion

Lubrication in pharmacy consists of adding, to a powder or a granule, a small amount of a lubricant, namely a substance capable, when inserted between two rough surfaces, of eliminating the projections and thus reducing friction. This work is devoted entirely to the study of the mechanism of granule lubrication and of pharmaceutical tablets. The lubricant selected was a magnesium stearate, and the lubricated material consisted of granules. For a better understanding of the distribution mode, a scanning electron microscope analysis was carried out, as well as a determination of magnesium stearate on the granule surface by microanalysis.

A relatively large number of investigations have been devoted to the study of the lubricant distribution on the surface of lubricated particles. Most of them have been carried out with magnesium stearate, and, as stated in the Introduction, three main possibilities have been pointed out (Fig. 7): (1) formation of a monomolecular film; (2) formation of a monoparticulate layer; and (3) mono- or multiparticulate filling of superficial cavities.

Prior to this work, most authors supported one of the latter two possibilities.

Some authors chose for the formation of monomolecular film. This type of conclusion generally derives from research focusing particularly on the effect of lubricant rate on the compression properties and on the tablet characteristics. This applies to Bolhuis et al. (1975). These authors, investigating the effect of magnesium stearate rate on the hardness of amylose V tablets, showed that the hardness became zero for a concentration approaching that necessary for the formation of a monomolecular film (0.025%).

Various authors chose for the formation of a continuous, uniform layer of the monoparticulate type. This type of conclusion is also generally the result of studies devoted to the influence of lubricant rate on the compression characteristics and on those of the granules or tablets (Tawashi, 1963a). This author investigated the flow characteristics of powders and granules after the addition of increasing concentrations of colloidal silica. Whatever the granule or powder, Tawashi showed that flow was optimal for the lubricant concentration required for the formation of a monoparticulate layer.

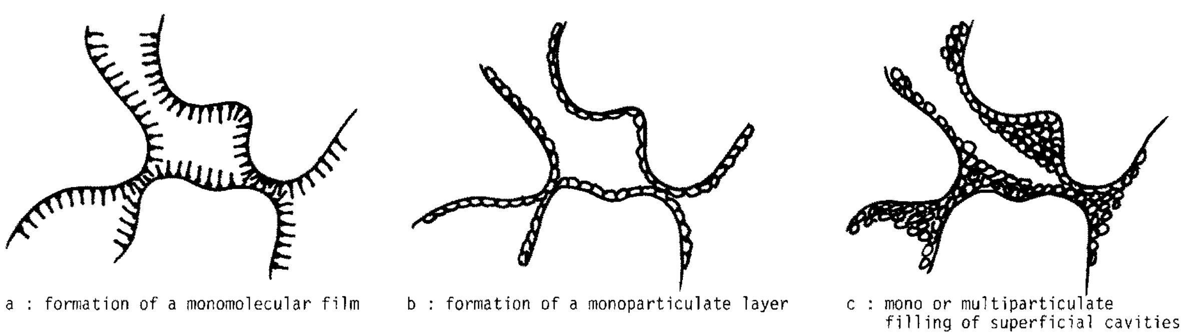

Fig. 7. Different kinds of lubrication.

Many authors chose for the simple filling of the cavities. This type of conclusion usually results from microscopic observations. Munzel and Kagi (1954), using stearic acid in solution, with an optical microscope, observed a non-uniform lubricant distribution on the surface of coal granules. List and Müller (1972), using Aerosil and magnesium stearate, proceeded with an examination of the lubricant distribution by scanning electron microsope. Aerosil, in a concentration of 0.3%, far from forming a continuous monoparticulate layer, rather tended to spread in the form of agglomerates in the surface cavities. However, the distribution of the stearate appears to be more homogeneous. Müller (1977), also using Aerosil, proposed two successive distribution modes: in the cavities for low concentrations, and on the projections for the higher concentrations. Using a scanning electron microscope, Bolhuis et al. (1975) pointed out the tendency of the magnesium stearate to lodge preferentially in the interstices of the lubricated material.

Pintye-Hodi et al. (1981), using an Edax microanalyzer, attempted to locate the magnesium stearate on the surface of particles of micronized trimetozine. Forced to work with a high lubricant concentration to offset the insufficient sensitivity of the method, they postulated a non-uniform distribution of the stearate on the particle surfaces.

Previously, investigations had been conducted in the laboratory (Roblot, 1982; Roblot et al., 1980, 1983a and b), including a microscope analysis and determinations during which the influence of lubricant rate on the compression characteristics and on the properties of the finished tablets, were assessed. The main data resulting from their analysis showed the following.

(1) The lubricant alters certain compression characteristics and properties of the tablets long before its concentration is sufficient to form a uniform layer of the monoparticulate type, and also long before its rate is adequate to fill all the superficial cavities. These remarks are valid for all compression characteristics (transmission ratio, compression energies) and even more for the tablet properties (hardness, disintegration time).

(2) The lubricant appears to display no tendency to spread on the surface of granules in a monoparticulate layer.

(3) However, the lubricant shows a tendency to lodge preferentially in the superficial cavities of the material to be lubricated. The existence of this localization appears to be confirmed by both the results of scanning electron microscope examination, those concerning the influence of stearate rate on the compression characteristics, and on the properties of the finished tablets.

The results obtained in previous investigations tend to confirm that the most probable distribution, in the conditions prevailing, is the one shown in Fig. 8. The stearate begins by filling the superficial cavities, and the steps to be considered are as follows: (1) partial filling of the cavities; (2) total filling of the cavities; and (3) formation of a peripheral layer of varying uniformity.

It is worthwhile noting that this suggestion shows good agreement with the variations observed in all the compression characteristics and all the properties analyzed in previous work (Roblot, 1983a and b).

For example, Fig. 6 shows that it agrees with the variation of a compression characteristic, the area of PI/PS cycles. The first phase of rapid decrease corresponds to the presence of more or

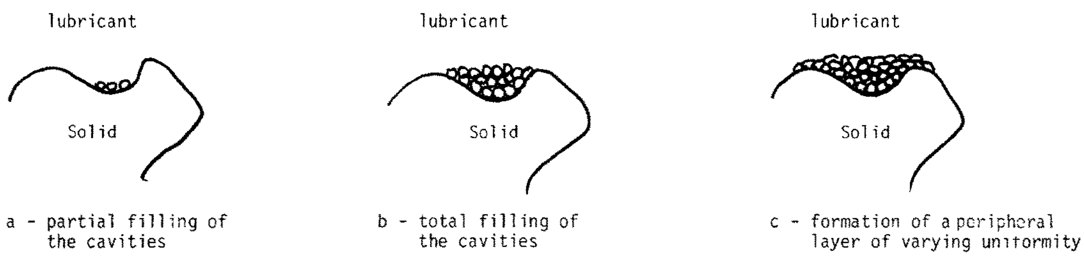

Fig. 8. Distribution of magnesium stearate during lubrication.

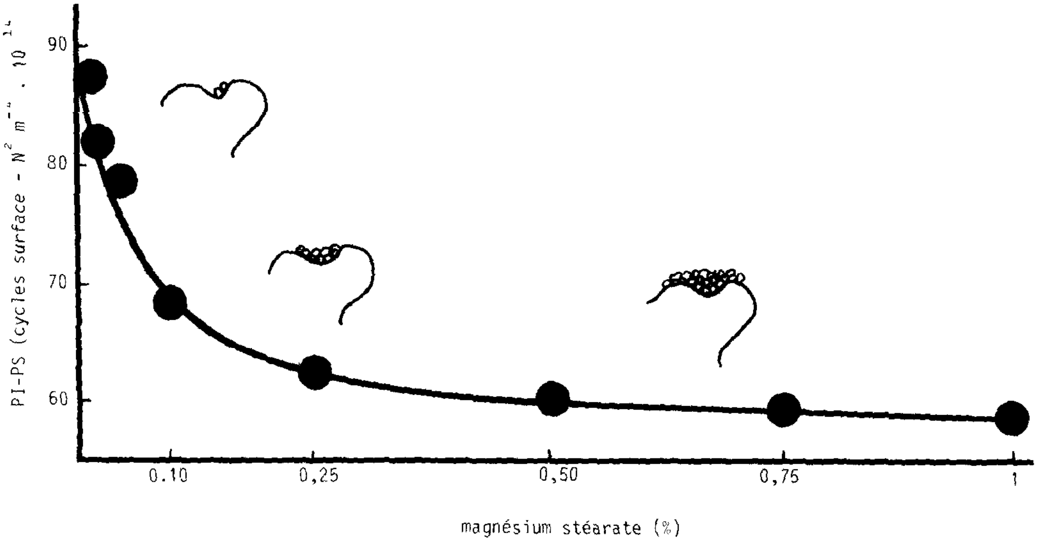

Fig. 9. Correspondence between distribution of magnesium stearate and variation of compression characteristic (PI/PS).

less isolated lubricant particles in the cavities, and finally to the appearance of excess stearate at the periphery. Displayed on a scanning electron microscope, this possibility is apparently confirmed by local and total microanalyses of magnesium on the granule surfaces.

The results obtained from this work do not in fact limit the role of magnesium stearate uniquely to the smoothing of irregularities. By forming a more or less regular layer, the stearate also reduces the interactions between moving surfaces. Resistance to sliding therefore depends at least partly on the shear strength of the lubricant film itself (Bowden and Tabor, 1964; Lewis and Train, 1965).

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