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Research paper

# Enteric coating of soft gelatin capsules by spouted bed: effect of operating conditions on coating efficiency and on product quality

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**Abstract**

The present study was conducted in order to analyze the viability of the spouted bed process for application of a gastric-resistant coating to soft gelatin capsules. The variables investigated were: included angle of conical base, ($\gamma$), the relation between the feed mass flow rate of the coating suspension and the feed mass flow rate of spouting gas ($W_s/W_g$); the ratio between the flow rate of the spouting gas and the flow rate at minimum spouting condition ($Q/Q_{ms}$); the mass of capsules in the bed ($M_0$), and the capsule's size. The product quality was measured by disintegration tests, traction × deformation tests, image analysis and by the evaluation of the coating mass distribution and shape factor variation during the coating operation. The experiments were performed in a spouted bed with a column diameter of 200 mm and included a conical base angle of 40°. The best coating efficiency values were obtained for $M_0 = 300$ g. Coating efficiency tended to increase with increasing $W_s/W_g$ ratio. Disintegration tests showed that the gastric-resistant effect was obtained with a coating mass of 3.86 mg/cm$^2$. The shape factor increase during the coating operation. The capsule's coating mass distribution tended to maintain the original distribution.


*Keywords:* Soft gelatin capsule; Spouted bed; Enteric coating; Coating efficiency; Kinetics growth

## 1. Introduction

Soft gelatin capsules are used to enclose powders or water-insoluble liquids dissolved in a non-polar solvent for several reasons, such as masking flavors or unpleasant smells, reducing contamination of the product, and protecting the active drug against oxidation. Capsules with gastric-resistant properties are employed to avoid degradation of the active substances by the gastric juice, and also to reduce gastric irritation caused by the medicine. The gastric-resistant coating allows the release of the medicine only at enteric pH. A survey of the literature showed few studies on the coating of soft gelatin capsules [1]. Therefore, the development of methods for applying a coating to these pharmaceutical forms is an important research topic.

In addition, the spouted bed has been widely used to apply coatings to agrochemical, chemical and pharmaceutical products such as seeds, pesticides, fertilizers, nuclear compounds and tablets. In particular, the advantage of the formation of highly uniform layers within relatively short periods of time has been attributed to the coating in spouted beds, due to excellent conditions of heat and mass transfer within the bed [2–4]. However, no papers regarding the coating of soft gelatin capsules using the spouted bed process are available in the literature.

The knowledge of the effect of operational conditions on the coating is important for the optimization of the process and of the product quality.

Due to the importance of the development of methods for applying coatings to soft gelatin capsules and to the potential of the spouted beds to perform this operation, the objective of the present investigation was to study the effect of operational conditions on the increase in capsule mass, on the kinetics of growth and on coating efficiency during the application of an enteric coating by this process. Disintegration tests were carried out in order to verify the gastric-resistant properties of the coated product. Traction × deformation tests were performed to verify the increase in the mechanical resistance of the capsules due to the coating layer. The capsule's coating mass distribution was measured by weighing. Traction × deformation tests were performed

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to verify the increase in the mechanical resistance of the capsules due to the coating layer. The coating layer structure was analyzed in photomicrographs obtained with a scanning electronic microscope. The results obtained in the present study can be used for the selection of optimal coating conditions that produce coated particles with good mechanical resistance and with few presences of fractures.

## 2. Materials and methods

### 2.1. Materials

#### 2.1.1. Capsules and coating composition

Soft gelatin capsules containing lecithin oil, kindly donated by RP-Scherer of Brazil Inc., were used as a support for coating application. The main compounds of the capsule shell were (in weight): gelatin (60.57%), glycerin (28.0%, as softening agent), water (11.18%) and preservative agents (0.25%). Two different sizes were used, 5 and 10, both with an oval format. The main physical characteristics of the capsules are presented in Table 1, where $m_{po}$ is the mean mass, $d_{pv}$ is the mean diameter, $\rho_p$ is the density, $S_e$ is the specific surface, and $\phi$ is the shape factor. The procedure used in these determinations has been described by Oliveira [5].

The coating formulation was composed of 0.25% of carboxymethyl cellulose, 4.85% of talc, 15.0% of Eudragit L-30-D-55 (a gastric-resistant polymer – dry basis), 20.0% of triethyl-citrate (related to the concentration of the polymer, as plastifying material) and distilled water. Table 2 shows some physical properties of this composition, where $\rho_f$, $\mu_f$ and $C_s$ are the density, viscosity, and solid content, respectively.

#### 2.1.2. Spouted bed

The equipment consists of a 400-mm cylindrical column with an internal diameter of 200 mm connected to conical bases with an included angle of 40° or 60° and an inlet orifice diameter of 52 mm. All parts are made of stainless steel. The experiments were monitored by means of a data acquisition system consisting of two pressure transducers (Model XL dp, Dresser Industries Inc.) and a temperature reading board (PCLD 789D; Advantech) connected to an acquisition board (PCL-711B; Advantech) installed in a personal computer running the LABTECH software. Fig. 1 is a schematic diagram of the experimental rig.

Table 1
Main physical characteristics of the capsules

| Size | $m_{po}$ (mg) | $d_{pv}$ (mm) | $\rho_p$ (g/ml) | $S_e$ (cm$^2$/g) | $\phi$ |
|---|---|---|---|---|---|
| 5 | 389 | 8.87 | 1.07 | 6.62 | 0.96 |
| 10 | 664 | 10.55 | 1.08 | 5.44 | 0.97 |

Table 2
Physical properties of the coating suspension used

| $\rho_f$ (g/cm$^3$) | $\mu_f$ (mPa) | $C_s$ (g/g) |
|---|---|---|
| 1.04 | 4.4 | 0.23 |

### 2.2. Experimental methods

#### 2.2.1. Fluid-dynamic characterization of the equipment

In order to determine the global parameters of the spouted bed, the maximum pressure drop, $\Delta P_m$, the pressure drop of stable spouting, $\Delta P_s$, and the minimum spouting flow rate, $Q_{ms}$, a fluid-dynamic characterization of the spouted bed was carried out. This characterization consisted of measurements of pressure drops in the bed of soft gelatin capsules as a function of introduced gas flow rate [6].

#### 2.2.2. Coating operation

The coating operation started with the introduction of a load of soft gelatin capsules into the bed. The spouting of this load was promoted by air injected at the base of the bed. As soon as spouting was established, the air was heated to the desired temperature. After reaching thermal equilibrium, feeding of coating suspension at a pre-set flow rate and ambient temperature, as well as the atomizing air were started. Samples of coated product were withdrawn every 15 min with a small ladle introduced into the spout zone. The samples were weighed and stored for subsequent tests. The inlet temperature of spouting gas was maintained at 55 °C in all experimental runs. The total coating time was kept at 45 min. The experimental data of the coating efficiency, $\eta$, were estimated by the following equation [7,8]:

$$\eta = \frac{n_0 \cdot (m_p - m_{p0})}{W_s \cdot C_s \cdot \theta} \quad (1)$$

In Eq. (1), $n_0$ is the initial number of the soft gelatin capsules in the bed, $m_{p0}$ is the initial mean mass of the capsules, $m_p$ is the mean capsule mass as a function of processing time, $\theta$,

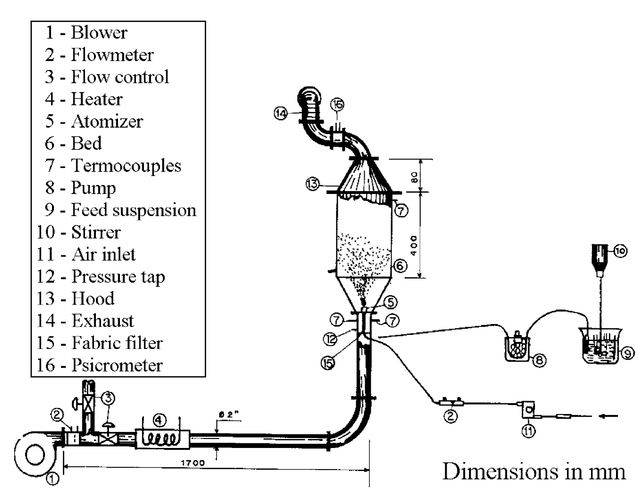


Fig. 1. Schematic presentation of the experimental rig used.

and $W_s$ and $C_s$ are, the mass feed flow rate and the solid content of the coating formulation, respectively.

*2.2.3. Gas temperature and humidity and variation of the capsules temperature during the coating process*

At beginning of the process and during the coating operation, measurements of the outlet gas temperature and humidity were made with the aid of a digital thermo-hygrometer (Traceable Digital Hygrometer/Thermometer/-Dew Point instrument, Control Co., USA). In some experiments the capsule's temperature were measured during the coating operation. Samples of capsules, withdrawn from the spouted bed during the coating operation at five minutes intervals, were placed quickly in an insulated bottle equipped with three thermocouples, connected to the data acquisition system. The capsule's temperature was monitored during one minute, being the mean value of this measurement adopted as the capsule temperature.

*2.2.4. Disintegration tests*

Disintegration tests were carried out to verify the gastric-resistant properties of the product. The capsules were placed in a disintegration apparatus, immersed in 0.1 M HCl at 37 °C, and the apparatus was turned on for 60 min. If the capsules were gastric-resistant, they were supposed not to become cracked or tumid by the end of the test. The capsules were then withdrawn and immersed in buffer at pH 6.8 (corresponding to the enteric pH), at a temperature of 37 °C. Under these conditions, the capsules should disintegrate completely in less than 45 min [9]. Several capsules representing different coating times and, consequently, coating thickness were tested.

*2.2.5. Capsule's mass, diameter and shape factor distributions during the coating operation*

The mass, diameter and shape factor distributions during the coating operation were measured as follows. Representative samples of 50 capsules were withdrawn from the bed at regular intervals. The coated and uncoated capsules were weighed individually and, with the aid of a micrometer, measured in two characteristic dimensions (bigger and smaller axis). By using these data the frequency distributions of mass, of the diameter and of the shape factor of the capsules could be calculated.

The diameter and the shape factor of the capsules were defined by the followings equations:

$$d_{pv} = \left(\frac{6 \cdot V_p}{\pi}\right) \tag{2}$$

and

$$\phi = \left(\frac{\pi \cdot d_{pv}^2}{S_p}\right) = \left(\frac{\text{Surface area of the equivalent sphere}}{\text{Surface area of the capsules}}\right) \tag{3}$$

In Eqs. (2) and (3), $V_p$ and $S_p$ are the capsule's volume and surface area, adopted, respectively, as the volume and the area of a prolate spheroid with the same characteristic axis of the capsules.

*2.2.6. Mechanical resistance of the coating*

The mechanical resistance of the coating was determined by conducting traction versus deformation tests up to the point where the coating fractured, using a Universal machine (Instron 5500 R). The tests continued until the capsules broke up. A cell load of 50 kgf was used. The objective of this study was to verify the variation in the mechanical resistance and in the physical characteristics of the capsules after application of the coating. First, the lecithin oil present inside the coated and un-coated capsules was removed with the aid of a needle attached to a syringe. Then, the empty capsules were cut through the middle, in the junction of the two shells. The two extremities of the cut capsules were fixed to the claws of the Instron machine. The displacement velocity was 0.5 mm/min and the analyses were performed in triplicate.

*2.2.7. Photomicrographs obtained by scanning electronic microscopy (SEM)*

For analysis of the quality of the coated surfaces, photomicrographs were obtained by SEM. First, the lecithin oil present in the capsules was removed according to the procedure described earlier. Then, the capsule was cut into small parts of approximately 0.5 cm. This procedure was adopted to avoid damage to the microscope during the measurements. These small parts were fixed on a metal support and subjected to coating with metallic gold and then transferred to the scanning electronic microscope (Zeiss DSM 960), where photomicrographs of the superficial layer of coated and uncoated soft gelatin capsules were obtained.

*2.2.8. Variables and operational conditions*

The variables analyzed were the ratio of the mass feed flow rate of the coating suspension to the mass feed flow rate of spouting gas, $W_s/W_g$; the ratio of feed flow rate of spouting gas to the feed flow rate at minimum spouting, $Q/Q_{ms}$, the included angle of the conical base, $\gamma$, and the initial bed mass, $M_0$. Table 3 shows the variables and operational conditions used. The flow rate of the atomization air was maintained at 15.0 l/min and a pressure of 1.5 kgf/cm$^2$.

Table 3
Variables and operational conditions used

| Variable | Range | Unit |
|---|---|---|
| $W_s/W_g$ | 0.0006–0.0022 | – |
| $Q/Q_{jm}$ | 1.6–2.6 | – |
| $\gamma$ | 40–60 | Degrees |
| $M_0$ | 150–300 | g |
| $C_s$ | 0.23 | g/g |

## 3. Results and discussion

### 3.1. Fluid-dynamic characterization of the spouted bed coater

No stable spouting was obtained with the included angle of the conical base of 60°. The small angle of the conical base had an undesirable effect on the circulation pattern of the capsules into the equipment. Using low flow rates of the spouting gas, the capsules were compacted on the wall of the equipment. Unstable spouts arose with larger flow rates. This behavior was not observed with the conical base with an included angle of 40°, for either capsule size or the initial bed loads studied. Thus, only the spouted bed with the included angle of 40° was used in the subsequent tests. With this configuration, the graphs of the pressure drop as a function of gas flow rate introduced into the system were similar to those reported in the literature. Fig. 2 presents typical results for $M_0 = 300$ g. The values of the maximum pressure drop, $\Delta P_m$, of the pressure drop of the stable spouting, $\Delta P_s$ and of the minimum spouting flow rate, $Q_{ms}$, were determined from the plots. Table 4 summarizes the results obtained for the different capsule sizes and initial mass loaded into the bed. The larger capsules showed greater values of minimum spouting flow-rate. The same relationship was observed when the initial load of the capsules into the bed was increased from 150 to 300 g. An increase of the bed load corresponds to an increase in maximum pressure drop. As expected, no effect on the maximum pressure drop was caused by the size of the capsules.

### 3.2. Coating operations

The best circulation patterns of the soft gelatin capsules inside the bed were obtained for a $Q/Q_{ms}$ ratio equal to 2.6, with this value being maintained in the coating tests. Fig. 3 shows the experimental results of the relative increase of the capsules mass as a function of coating time using the $W_s/W_g$ ratio as a parameter (number 5 capsules). The figure shows that capsule mass increases linearly with processing time, corroborating previous results presented in the literature [8,10,11]. Similar results were obtained for size 10 capsules. The experimental values of coating efficiency, $\eta$, were determined from the results of the relative increase in capsule mass as a function of coating time obtained for all experimental runs. Fig. 4a and b respectively present coating efficiency as a function of capsule size and of the $W_s/W_g$ ratio for the two bed loads studied. From the graphs presented, we may conclude that capsule size had small influence on coating efficiency. Also, for $M_0$ of 150 g, coating efficiency tended to increase with an increasing $W_s/W_g$ ratio. However, intermediate $W_s/W_g$ values reduced the occurrence of problems such as the agglomeration of capsules during the coating process. Higher coating efficiency was obtained for $M_0$ of 300 g. This result was attributed to the better contact between the coating suspension and the capsules in the atomizing zone, avoiding the elutriation of the coating composition with the effluent gas. The similarity between the graphs presented in Fig. 5a and b confirms that capsule's size had no effect on coating efficiency.

Table 4
Fluid-dynamic parameters of the spouted bed

| Capsule size | $M_0$ (g) | $\Delta P_m$ (N/m$^2$) | $\Delta P_s$ (N/m$^2$) | $Q_{ms}$ (m$^3$/min) |
|---|---|---|---|---|
| 5 | 150 | 242 | 150 | 0.63 |
| 5 | 300 | 345 | 150 | 0.95 |
| 10 | 150 | 250 | 75 | 0.75 |
| 10 | 300 | 364 | 75 | 1.05 |

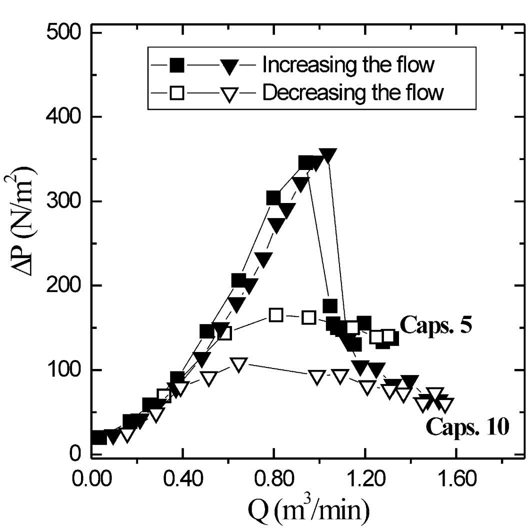


Fig. 2. Typical plots of pressure drop as a function of spouting gas flow rate using capsule size as a parameter ($M_0 = 300$ g and $\gamma = 40$ °C).

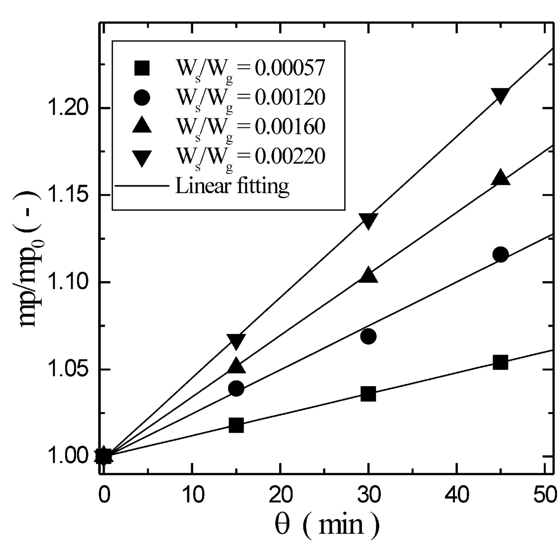


Fig. 3. Typical graphs of the relative increase in mass of the soft gelatin capsules as a function of coating time using the $W_s/W_g$ ratio as a parameter (capsule 5).

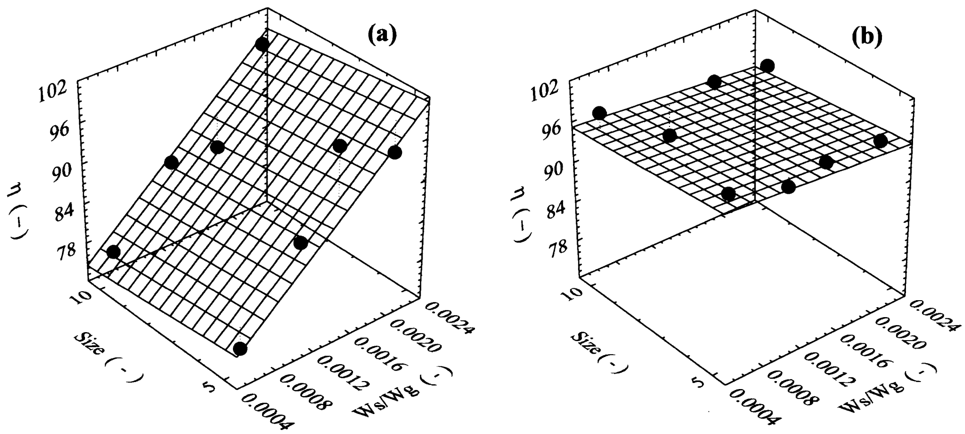


Fig. 4. Coating efficiency as a function of capsule size and of the $W_s/W_g$ ratio, for $M_0 = 150$ g and 300 g, (a) and (b), respectively.

*3.3. Gas temperature and humidity and variation of the capsules temperature during the coating process*

The relative humidity of the gas (percentile), was measured at beginning of the process and during the coating operation for some experiments. At the beginning of the process the percentage relative gas humidity reach a nearly constant value of 16.5 ± 1.4% for an outlet gas temperature of 53.0 ± 0.5 °C (approximately 0.016 kg water/kg dry gas). During the coating operation the relative gas humidity showed a slightly increase, depending on the operating conditions employed. In the experiments were this parameter was measured, the relative gas humidity reached the value of 21.0 ± 1.0% at an outlet gas temperature of 50.0 ± 1.5 °C.

Another aspect to be considered is the temperature that the capsule reaches during the coating process. At elevated temperatures, the soft gelatin capsules usually become very soft. This is a characteristic unfavorable to the coating operation, leading to the blocking of the process due to the cessation of the spouting of the capsules into the bed. However, due to the evaporation of the coating in the capsules surface, the temperature reached by the capsule is considerably lower than the temperature of the inlet gas. During the coating operation, the capsule temperature increased from the initial value of 30.0 ± 0.5 °C to the steady-steady value of 47.0 ± 1.0 °C in about 10 min of process. In this time, the growth of the coating layer gives an extra protection against the extreme heating on the capsules shell, avoiding the denaturizing of the capsules.

*3.4. Gastric-resistance tests*

The capsules were placed in a medium containing 0.1 M HCl at 37 °C and the disintegration apparatus was activated for 60 min. During the test, only the samples with a coating mass of less than 3.86 mg/cm$^2$ appeared tumid or presented content leakage. At the end of this test, the capsules were immersed in the buffer, pH 6.8, at a temperature of 37 °C. The disintegration time in this solution should be less than 45 min (or a total of 105 min when adding the time spent in the acid medium). All capsules had already disintegrated before the end of this test. Fig. 6 shows the total disintegration time, $\theta$, as a function of the ratio between the coating mass adhered and the surface area of the gelatin capsule, $m_r/A_c$.

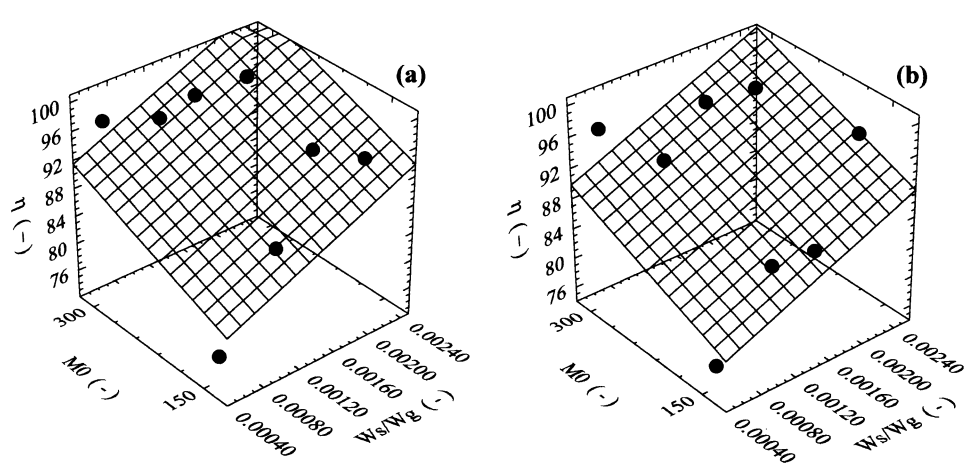


Fig. 5. Coating efficiency as a function of the initial mass of capsules in the bed for capsules 5 and 10, (a) and (b), respectively.

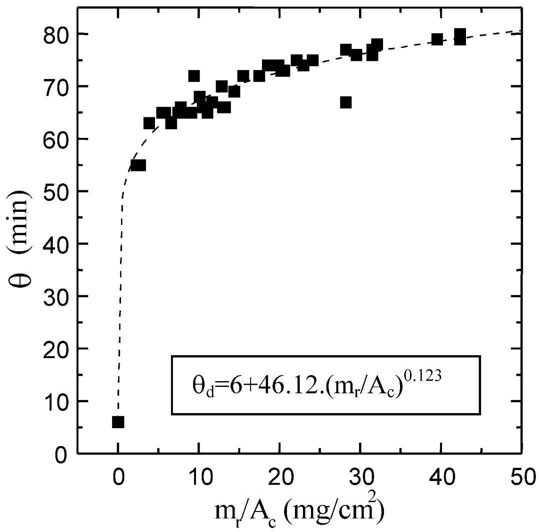


Fig. 6. Disintegration time as a function of the $m_r/A_c$ ratio.

The results confirm the efficiency of this method of application of enteric coating and lead us to conclude that the gastric-resistant effect is directly dependent on the thickness of the coating layer. Tests performed with uncoated capsules showed that the normal disintegration time, $\theta_d$, was 6 min in acid medium for both capsule sizes used.

An equation relating the disintegration time as a function of the ratio between the coating mass adhered and the surface area of the gelatin capsule, $m_r/A_c$, was obtained by non-linear regression.

The following equation, with a correlation coefficient higher than 0.98, was obtained:

$$\theta_d = 6 + 46.12 \cdot (m_r/A_c)^{0.123} \quad (4)$$

Fig. 6 shows the good agreement between the experimental results and the estimates obtained by Eq. (4), indicating their applicability for the optimization of the operating conditions of the spouted bed coating of these types of pharmaceutical dosage forms.

*3.4.1. Capsule's mass, diameter and shape factor distributions during the coating operation*

The unitary mass as well as the two characteristics dimensions (bigger and smaller axis) of 50 capsules were measured at beginning of the process (uncoated capsules), at 20 min of operation and at end of the process (45 min), in order to verify the coating uniformity. From these data were possible to determine the frequency distributions of mass, of the diameter and of the shape factor of the capsules. Typical results of the frequency distributions of mass, of the diameter and of the shape factor of the capsules are presented in Fig. 7a, b and c, respectively. From Fig. 7a, it can be observed that the capsule's coating mass distributions tends to maintain the initial distribution during the coating operation, indicating that the total amount of coating

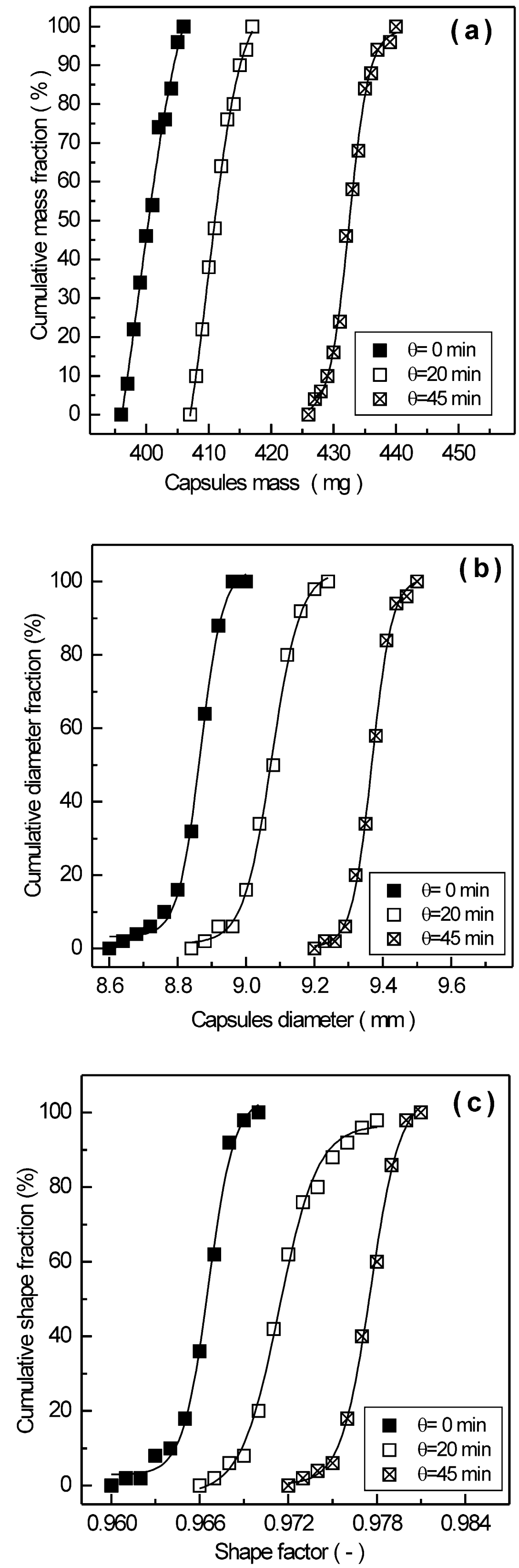


Fig. 7. Typical results of frequency distributions of mass, of the diameter and of the shape factor of the capsules, (a), (b) and (c), respectively (capsule 5, $M_0$ = 300 g and $W_s/W_g$ = 0.0012).

received by each capsules were similar. This is an expected behavior since the capsules used in this study have a narrow mass and diameter distributions, with a variation less than 1% both in mass and in size as well, which was maintained during the coating operation. It is knew that that the total amount of coating applied on each particle depends on the coating applied in each pass and of the total number of passes in the atomization zones the particle experiences during the operation [12]. These two factors are dependent of the physical properties of the particles (similar in this study), and of the configuration and operating conditions of the equipment, which should prevent the occurrence of dead zones and other problems associated with this complex operation [13], problems not detected in our study. All these factors, similar physical properties of the raw material, absence of dead zones in the equipment and best configuration (selected in the fluid-dynamic studies), probably may have contributed to the maintenance of mass and diameter distributions during the coating operation.

From Fig. 7c, it can be observed that the shape factor of the capsules show a tendency to increase during the coating operation, indicating a non-uniform coating mass distribution over the whole capsules surface. Measurements of the bigger and of the smaller characteristic axis of the capsules confirm these results, indicating that the coating deposits preferentially in the central part of the capsules (small axis), while the extremities receives only a small amount of coating. The same behavior was observed during tablet coating operations, using similar equipment [5,10]. This information is relevant and should be considered during the development of special applications like the gastric resistant and sustained release coatings.

### 3.4.2. Resistance × deformation tests

The coated soft gelatin capsules become visibly more rigid and less elastic than the uncoated capsules. This observation was confirmed by the traction × elongation tests. The ratio between the coating mass adhered and the capsule surface area, $m_r/A_c$; and the fracture force and maximum elongation before rupture are presented in Fig. 8. From these graphs it can be deduced that the resistance to traction of the capsules and the maximum extension of elongation are dependent on the amount of the coating mass adhered to the capsules surface area, $m_r/A_c$. The value of the elongation measured for the coated and uncoated capsules presents a significant difference. This value decreased with increasing amount of the coating mass adhered to the capsules surface area in the different samples analyzed. This behavior confirms that the soft gelatin become less elastic due to the application of the coating.

The rupture point considered for the measurement of dislocation was the point where the capsule, and not the coating material, ruptured. In most samples analyzed, the material adhered to the surface of the capsules became detached and broke before the gelatin film. This was due to

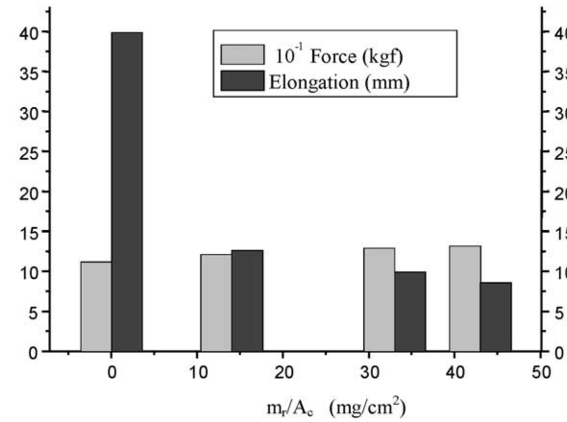


Fig. 8. Relationship between the coating mass adhered and the capsule surface area, $m_r/A_c$; fracture force and maximum elongation before capsule rupture.

the low level of interface forces between the polymer and the gelatin capsules which impaired polymer adhesion to the surface of the capsule. The weak adhesion between these two materials may have been due to the insufficient amount of plastifying material, triethyl acetate, contained in the coating suspension, as observed by Felton and McGinity [14].

Some interaction between coating material and capsule shell material may probably exist even if the interface forces between these two materials are not so strong. This interaction may be of a physical nature since the adhered material becomes hard and brittle and may mechanically damage the gelatin. Some gelatin denaturation may also have occurred during the process, which was conducted at relatively high temperatures [15]. However, the results obtained when two capsule samples with the same mass of coating material adhered were used but with different coating times showed no significant difference.

In order to verify the effect of the amount of plastifying material on the capsule's elasticity, some compression tests were carried-out. The results of these experiments, presented in Fig. 9, confirmed that resistance to deformation depends on the amount of plastifying material used. The

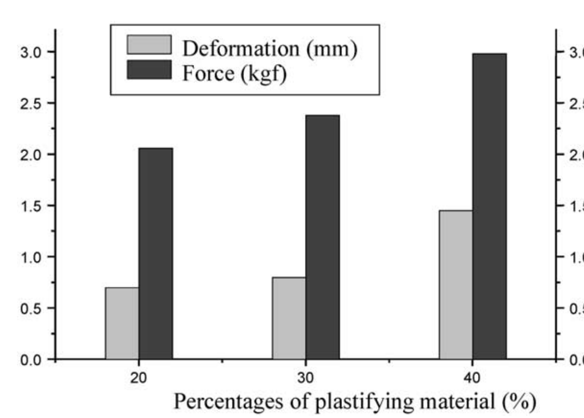


Fig. 9. Relation between the percentages of plastifying material, maximum compression force and maximum dislocation suffered by the capsules.

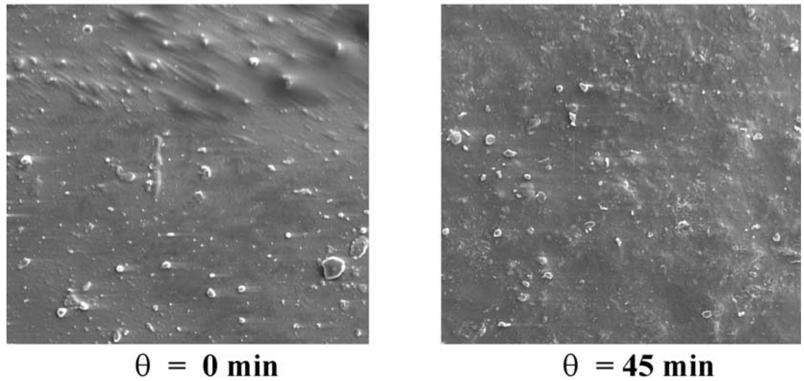


Fig. 10. Typical photomicrographs of an uncoated and a coated gelatin capsule (capsule 5, $M_0 = 300$ g and $W_s/W_g = 0.0022$).

larger the amount of this material in the coating suspension, the more resistant and malleable the polymer layer becomes. Fig. 8 shows that both the compression force needed to fracture the coating and the maximum dislocation (compression) suffered by the capsule increase with increasing percentage of plastifying material.

According to Thoma and Bechtold [16], the plastifying material increases the mobility of the molecular chain, at least on the surface of dispersed particles. In addition, the plastifying agent facilitates the film effect produced by the sliding of interconnected polymer chains.

### 3.4.3. Photomicrographs obtained with a scanning electron microscope

In the analysis of the photomicrographs the size and the number of irregularities on the coated surface of the capsule were taken into account. Fig. 10 shows typical photomicrographs of the surface of an uncoated capsule and a coated capsule, at 100× magnification. It was observed that the uniformity of the coating increased with an increasing $W_s/W_g$ ratio. A better quality of the coated surface was observed for longer coating times. When higher $W_s/W_g$ ratios are used, the drying time of the atomized droplet adhered to the capsule is longer. Consequently, the coating has sufficient time to spread onto the capsule surface. Thus, each droplet forms a small-coated zone on the coating surface, facilitating the homogenization of the coating film formed. The dependence of the film uniformity on coating time can be explained by the number of times the capsule passes through the atomizing area, which is larger for longer processing times. Thus, the coating layer becomes more uniform.

## 4. Conclusions

On the basis of the above considerations, the following conclusions can be drawn:

For the two sizes of soft gelatin capsules used, no stable spouting was obtained in the spouted bed with an included conical base angle of 60°.

The mass of the capsules increases linearly with coating time, regardless of the experimental conditions used.

The size of the capsule has no effect on the coating efficiency.

The coating process was more efficient for $M_0$ equal to 300 g.

Coating efficiency tended to increase with an increasing $W_s/W_g$. However, intermediate $W_s/W_g$ values reduce the probability of occurrence of problems such as cracks and agglomeration of capsules during the process.

A ratio between the coating mass and the surface area of soft gelatin capsule equal to 3.86 mg/cm$^2$ is sufficient to obtain the gastric-resistant effect.

The disintegration time as a function of the relation between the coating mass adhered and the surface area of the soft gelatin capsule, $m_r/A_c$, can be described by Eq. (4) (Section 3.4).

The shape factor increase during the coating operation.

The capsule's coating mass distribution tended to maintain the original distribution.

From the analysis presented, we may conclude that the spouted bed is a fast and efficient method for the application of enteric coating to soft gelatin capsules.

## Acknowledgements

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