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Force-displacement parameters of maltodextrins after the addition of lubricants

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Abstract

The effect of the presence of lubricants on the tableting properties of Maltrin® M510 and M150 was examined using an instrumented single punch tablet press. The lubricants studied were the classical magnesium stearate as well as PRUV® and PRECIROL®. The energy balance parameters have been discussed in relation with the three lubricants and the conditions established in the study (concentration of lubricant, mixing time and applied pressure). The expansion work and the net apparent work did not distinguish between both maltodextrins. Although M150 presented more capacity to form compacts than M510, it showed higher friction during compression. The addition of lubricants decreased the friction work and increased the expansion work. The bonding characteristics indicated that PRECIROL® was the lubricant that disminshed it to a greater extent, probably due to its morphological properties. It presents a small size in comparison with the other two lubricants under study and occupied more places between particles. The effect of concentration and mixing time was variable and different for both maltodextrins due to a slightly insensitivity showed by M150. The higher the applied pressure was, the higher expansion and net apparent work was obtained, showing a linear regression. When the expression for friction work proposed by Juslin was considered, the regression fit was better than with de Blaey's equation. The study of plasticity in relation with applied pressure showed that over 100 MPa there was a limit of plastic deformation for these maltodextrins. © 1997 Elsevier Science B.V.

Keywords: Lubricants; Maltodextrins; Friction; Compressional behaviour; Magnesium stearate

1. Introduction

The knowledge of the consolidation mechanism of tablet diluents is important to understand the suitability and limitations of the excipient for specific tableting functions. Also, the friction is

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another factor which should be known in studies of the compaction process. Several parameters as well as different ways to calculate them have been the aim of previous papers (Järvinen and Juslin, 1974; Ragnarsson and Sjögren, 1985, 1983).

Lubricants in tablet formulations may decrease tablet strength. The mechanism of such decrease is thought to be due to the lubricant particles coating the larger excipient particles and interrupting interparticulate bonding. Fragmentation of brittle particles results in large areas of new unexposed surfaces reducing the detrimental effect of a lubricant on tablet strength. Plastic deformation does not produce the same extend of new particle surfaces and the tablet strength of these materials is typically more sensitive to lubricants (Vromans et al., 1988). Thus, the sensitivity of tablet strength to the presence of a lubricant can be used to assess the consolidation mechanism.

Maltodextrins are composed of water-soluble glucose polymers obtained from the reaction of starch with acid and/or enzymes in the presence of water. Li and Peck (1990a,b) stated that the method of granulation had an influence on the physical properties of maltodextrins and that the moisture content of the material exerted an effect on its compaction behaviour. Papadimitriou et al. (1992) evaluated Maltrin® as excipients direct compression as well as their influence on the rate of dissolution. Mollan and Çelik (1993, 1994) started with the characterization of 5 types of maltodextrins manufactured by different methods, and later evaluated their mixtures with acetominophen. Recently Mollan and Çelik (1995), have also studied the effects of humidity and storage time on the behaviour of maltodextrins for direct compression.

M150 shows problems with its manufacture due to high friction between the tablet and die wall and the adhesion of the tablet to the punches or die wall as well as for its stickiness in comparison with other maltodextrins such as M510, QD M500 and QD M550. So for this reason, the use of lubricants seems to be necessary (Shah et al., 1986; Muñoz-Ruiz et al., 1993). Magnesium stearate is the most commonly used tableting lubricant (Miller and York, 1988). Sodium stearyl fumarate and glyceryl palmito-stearic were also studied because they are relatively new and has been reported to be less prone to tablet strength (Delattre et al., 1976; Risk et al., 1995).

Although the physical and chemical characteristics of the materials are the cause of their behaviour, the instrumented tablet machines are considered the best tool to evaluate friction during tableting (Delacourte et al., 1987). Friction parameters during compression are frequently used to characterize this process, however energy balance parameters are sometimes more sensible to get this aim (De Blaey and Polderman, 1970).

For this reason, the aim of this study is to evaluate the compressional behaviour of M510 and M150 after the addition of lubricants at different conditions as well as to discuss the availability of certain parameters derived from force-displacement curves to study the different conditions.

2. Materials and methods

In this study, two excipients for direct compression are used: Maltrin® M150, batch T0466 and Maltrin® M510, batch G0705 (Grain Processing Corporation, Iowa, Muscatine, USA).

Three lubricants were also used: magnesium stearate, batch 920844 (Dr Esteve, Barcelona, Spain); PRUV®, sodium stearyl fumarate, batch 139-01 (Juliá-Parrera, Barcelona, Spain) and PRECIROL®, glyceryl palmito-stearic ester, batch 18832 (Gattefossé, Saint-Priest Cedex, France).

The excipients were mixed for two mixing times (2 and 10 min) with three different concentrations (0.5, 1 and 2%) of magnesium stearate, PRUV® and PRECIROL®, in a vessel in an asymmetric double-cone mixer (Retsch, Haan, Germany) at 50 rev min^{-1}.

The image analysis of the materials has been carried out in a SEM Philips XL 30 (Philips, Netherlands) with the aid of a program of acquistion and reduction of data (Soft Imaging Software, Germany).

The friction parameters of the mixtures were investigated using an instrumented single-punch tablet machine (Bonals, model AMT 300,

Table 1
Results of expansion work (EW in J), net apparent work (NAW in J) and plasticity (Pl adimensional) for mixtures of Maltrin® M150 and M510 with magnesium stearate (average of three tablets and S.D.)

Conditions	M150			M510		
	EW (J)	NAW (J)	Pl (−)	EW (J)	NAW (J)	Pl (−)
A1	2.092 (0.193)	19.21 (0.23)	90.18 (0.90)	1.869 (0.241)	20.07 (0.35)	91.49 (1.04)
A2	0.821 (0.016)	9.45 (0.07)	92.01 (0.10)	0.959 (0.066)	11.58 (0.09)	92.35 (0.51)
A3	0.599 (0.083)	6.56 (0.27)	91.67 (0.76)	0.113 (0.071)	6.80 (0.09)	98.37 (1.02)
B1	1.629 (0.325)	18.39 (0.34)	90.78 (0.23)	2.539 (0.120)	19.77 (0.18)	88.62 (0.40)
B2	0.683 (0.091)	9.30 (0.17)	93.15 (0.96)	1.014 (0.067)	10.72 (0.38)	91.37 (0.25)
B3	0.543 (0.010)	5.77 (0.04)	91.47 (0.09)	0.640 (0.078)	6.032 (0.15)	90.43 (0.88)
C1	2.585 (0.437)	18.51 (0.24)	87.77 (1.83)	1.982 (0.160)	19.94 (0.32)	90.97 (0.58)
C2	0.926 (0.059)	9.09 (0.11)	90.75 (0.64)	1.096 (0.066)	10.87 (0.13)	90.85 (0.40)
C3	0.608 (0.032)	5.56 (0.09)	90.15 (0.51)	0.714 (0.044)	6.80 (0.07)	90.50 (0.45)
D1	2.691 (0.073)	19.87 (0.13)	88.07 (0.24)	3.032 (0.281)	18.77 (0.27)	86.11 (1.06)
D2	0.995 (0.105)	10.33 (0.34)	91.07 (0.67)	1.050 (0.080)	9.84 (0.08)	90.36 (0.70)
D3	0.632 (0.009)	6.19 (0.19)	90.74 (0.19)	0.640 (0.016)	6.49 (0.02)	91.02 (0.21)
E1	2.623 (0.159)	19.08 (0.16)	87.91 (0.72)	2.980 (0.29)	17.95 (0.20)	85.78 (1.15)
E2	0.890 (0.092)	9.27 (0.39)	91.54 (0.53)	1.178 (0.051)	9.26 (0.10)	88.71 (0.511)
E3	0.723 (0.044)	6.09 (0.15)	89.38 (0.75)	0.548 (0.012)	6.067 (0.15)	91.70 (0.35)
F1	2.501 (0.083)	18.09 (0.27)	87.85 (0.51)	2.298 (0.817)	17.89 (0.25)	86.45 (1.03)
F2	0.941 (0.041)	9.85 (0.12)	91.28 (0.27)	0.430 (0.082)	9.907 (0.09)	95.85 (0.75)
F3	0.487 (0.031)	6.65 (0.10)	93.19 (0.30)	0.839 (0.129)	5.380 (0.17)	86.56 (1.51)

Barcelona, Spain). Displacement were corrected with punch deformation (Muñoz-Ruiz et al., 1995). A quantity of powder sufficient to produce tablets 4 mm thick at zero theoretical porosity was manually filled into the die (12 mm). Flat compacts were prepared at 3 different applied pressures (50, 100 and 200 MPa).

The breaking strength was determined immediately after compression by placing each tablet in a commercially available hardness tester (Schleuniger-2E, Dr K. Schleuniger, Greifensee, Switzerland). The tensile strength was calculated according to Fell and Newton (1970).

The nomenclature used to identify the conditions is: A (0.5%, 2 min); B (0.5%, 10 min); C (1%, 2 min); D (1%, 10 min); E (2%, 2 min) and F (2%, 10 min). The tablet batches compressed at different applied pressures are distinguished as follows: 1 (200 MPa); 2 (100 MPa) and 3 (50 MPa).

Data were analyzed using Student's t-test and an analysis of the variance (ANOVA) according with the design of the experimental conditions chosen.

3. Results and discussion

3.1. *Force-displacement parameters and comparison between maltodextrins*

Tables 1–3 show the compressional parameters for two maltodextrins with the lubricants used in the study. Compressional work describes the total amount of mechanical energy needed to compress a loose powder column into a dense tablet. Three components can be differenciated in this work: energy to overcome the friction, energy consumption in expansion of the tablet after the maximum compression and finally energy for bonding and formation of firm compacts.

Because the problems of the double compression technique (De Blaey and Polderman, 1970) to evaluate the expansion work, in our case this parameter has been calculated as the work exerted on the upper punch from the maximum displacement to the displacement where the force exerted during decompression is zero. The expansion work of both maltodextrins (Tables 1–3) were statistically indistinguishable between them (Student's t-test, 2.97; $p > 0.05$).

Table 2
Results of expansion work (EW in J), net apparent work (NAW in J) and plasticity (Pl adimensional) for mixtures of Maltrin® M150 and M510 with PRUV® (average of three tablets and S.D.)

Conditions	M150			M510		
	EW (J)	NAW (J)	Pl (−)	EW (J)	NAW (J)	Pl (−)
A1	2.479 (0.060)	20.06 (0.20)	88.99 (0.32)	2.971 (0.126)	19.57 (0.16)	86.82 (0.46)
A2	0.896 (0.048)	10.10 (0.21)	91.86 (0.25)	1.185 (0.021)	10.30 (0.10)	89.68 (0.19)
A3	0.411 (0.049)	7.375 (0.13)	94.72 (0.65)	0.841 (0.051)	6.92 (0.19)	89.17 (0.32)
B1	2.775 (0.174)	19.23 (0.47)	87.40 (0.42)	2.621 (0.108)	20.59 (0.05)	88.71 (0.40)
B2	1.227 (0.023)	10.42 (0.14)	89.51 (0.22)	0.974 (0.049)	10.25 (0.11)	91.32 (0.48)
B3	0.667 (0.009)	6.899 (0.16)	91.17 (0.25)	0.632 (0.030)	6.53 (0.34)	91.19 (0.18)
C1	2.643 (0.186)	18.49 (0.31)	87.51 (0.59)	2.186 (0.218)	19.69 (0.16)	90.02 (0.83)
C2	0.934 (0.045)	9.106 (0.23)	90.68 (0.60)	0.716 (0.160)	11.04 (0.58)	93.97 (0.97)
C3	0.588 (0.032)	5.999 (0.13)	91.07 (0.46)	0.559 (0.034)	7.30 (0.17)	92.90 (0.24)
D1	2.887 (0.095)	18.45 (0.30)	86.47 (0.47)	1.878 (0.575)	19.36 (0.27)	89.58 (0.09)
D2	1.150 (0.076)	8.988 (0.05)	88.66 (0.61)	0.846 (0.043)	11.47 (0.15)	93.13 (0.40)
D3	0.713 (0.018)	5.328 (0.12)	88.20 (0.22)	0.519 (0.028)	7.13 (0.18)	93.22 (0.22)
E1	3.121 (0.160)	17.34 (0.23)	84.75 (0.69)	2.680 (0.17)	18.43 (0.03)	87.31 (0.67)
E2	1.169 (0.065)	8.478 (0.08)	87.88 (0.52)	0.825 (0.035)	10.08 (0.32)	92.43 (0.44)
E3	0.680 (0.021)	5.329 (0.06)	88.69 (0.21)	0.740 (0.059)	6.72 (0.26)	90.09 (0.49)
F1	2.858 (0.051)	16.66 (0.10)	85.36 (0.14)	3.010 (0.182)	16.54 (0.18)	84.60 (0.93)
F2	1.162 (0.037)	9.097 (0.01)	88.67 (0.31)	1.020 (0.036)	9.35 (0.29)	90.16 (0.03)
F3	0.684 (0.016)	5.164 (0.08)	88.30 (0.33)	0.692 (0.030)	6.64 (0.07)	90.57 (0.38)

De Blaey and Polderman (1970) defined friction work as the integral of the difference between the upper punch force and the lower punch force. Later, Järvinen and Juslin (1974) supposed that the movement of the particles depends linearly with the distance of the upper punch. Also, the distribution of the axial force according to Unckel's equation (1945) decreases exponentially from the upper to the lower punch (Unckel, 1945):

$$W_{\text{fric}} = \int_{h_1}^{h_2} \frac{F_U - (F_U - F_L)}{\ln F_U/F_L} dh$$

where the height of the column changes from h_1 a h_2 during the compresion, F_U is the upper force and F_L the lower punch force.

M510 tablets showed less friction than M150 according to both expressions. Juslin friction work was approximately half the friction work proposed by de Blaey. Thus, de Blaey friction work was statistical different (Student's t-test, 3.052, $p < 0.01$), being the media equal to 1.587 J for M510 and 1.826 J for M150. Juslin friction work was also a sensitive parameter and distinguished statistically between both maltodextrins (Student's t-test, 3.125; $p < 0.01$), 0.814 J in M510 and 0.936 J in M150, being the media.

The net apparent work is calculated as the difference of the applied work and the expansion work (Tables 1–3). According to this parameter, no statistical difference was found between M510 and M150 mixtures (Student's t-test, 2.36; $p > 0.05$). But if the friction work is also subtrated because it does not contribute to the formation of the compact, (Järvinen and Juslin, 1974) no statistical difference was observed between both maltodextrins (Student's t-test, 1.82; $p > 0.05$), if Juslin friction equation is used (Järvinen and Juslin, 1974); whereas if de Blaey expression (De Blaey and Polderman, 1970) was considered, statistical difference was observed (Student's t-test, 2.09; $p < 0.05$) due to the overestimation of the friction (Ragnarsson and Sjögren, 1983).

Plasticity values are calculated from the following relation:

$$\%\text{Pl} = \frac{W_{\text{NA}}}{W_{\text{NA}} + W_{\text{EX}}}$$

Table 3
Results of expansion work (EW in J), net apparent work (NAW in J) and plasticity (PI adimensional) for mixtures of Maltrin® M150 and M510 with PRECIROL® (average of three tablets and S.D.)

Conditions	M150			M510		
	EW (J)	NAW (J)	PI (–)	EW (J)	NAW (J)	PI (–)
A1	3.073 (0.157)	18.48 (0.20)	85.74 (0.64)	2.371 (0.129)	19.62 (0.29)	89.19 (0.38)
A2	1.217 (0.003)	9.44 (0.03)	88.58 (0.31)	1.067 (0.038)	11.08 (0.04)	91.21 (0.32)
A3	0.791 (0.021)	5.51 (0.19)	87.44 (0.57)	2.098 (1.354)	0.63 (0.86)	76.02 (14.62)
B1	2.546 (0.113)	17.87 (0.25)	87.52 (0.62)	2.225 (0.201)	19.61 (0.32)	89.83 (0.69)
B2	0.958 (0.049)	8.40 (0.12)	89.76 (0.53)	1.007 (0.020)	10.61 (0.36)	91.32 (0.28)
B3	0.890 (0.102)	5.60 (0.27)	86.38 (1.87)	0.856 (0.058)	7.80 (0.22)	90.11 (0.61)
C1	2.280 (0.042)	17.22 (0.34)	88.31 (0.02)	1.779 (0.128)	19.23 (0.32)	91.53 (0.58)
C2	0.984 (0.020)	8.27 (0.12)	89.37 (0.10)	0.807 (0.060)	10.34 (0.26)	92.76 (0.62)
C3	0.757 (0.035)	5.85 (0.21)	88.54 (0.21)	0.627 (0.019)	7.42 (0.03)	92.21 (0.24)
D1	2.354 (0.251)	17.04 (0.43)	87.90 (0.87)	5.275 (3.485)	16.85 (2.79)	76.62 (14.69)
D2	1.143 (0.074)	8.42 (0.42)	88.04 (0.54)	1.036 (0.041)	10.16 (0.03)	90.75 (0.30)
D3	0.618 (0.059)	5.49 (0.16)	89.87 (0.94)	0.755 (0.003)	7.35 (0.12)	90.68 (0.13)
E1	2.110 (0.278)	16.12 (0.66)	88.47 (0.97)	3.312 (0.184)	16.65 (0.21)	83.43 (0.58)
E2	1.622 (0.423)	8.078 (0.42)	83.27 (4.37)	1.125 (0.045)	8.77 (0.24)	88.64 (0.11)
E3	0.521 (0.051)	5.13 (0.07)	90.79 (0.74)	0.477 (0.064)	7.61 (0.16)	94.10 (0.75)
F1	1.896 (0.253)	16.49 (0.03)	89.71 (1.24)	3.320 (0.19)	16.53 (0.22)	83.29 (0.60)
F2	0.446 (0.066)	8.52 (0.16)	95.01 (0.78)	1.38 (0.075)	9.43 (0.22)	87.24 (0.55)
F3	0.233 (0.030)	4.99 (0.15)	95.55 (0.56)	0.859 (0.071)	6.07 (0.13)	87.62 (0.85)

where: W_{NA} is the net apparent work, and W_{EXP} is the expansion work.

No statistical difference was found between M510 and M150 mixtures (Student's t-test, 0.84; $p > 0.05$). Similar results were found previously (Muñoz-Ruiz et al., 1993), M510 plasticity being higher than M150 in unlubricated conditions and this difference disappears after the addition of lubricants.

For the compaction of materials and formation of strong compacts energy is needed, and it seems more logical to correlate the properties of the compact with the energy input rather than with the applied pressure. In this paper, the cohesion index is calculated as the ratio of tensile strength and net apparent work (Delacourte et al., 1993). Figs. 1–3 depict the values of the cohesion index for the different conditions of concentration and applied pressure. This parameter, that reflects the bonding characteristics of the particles, distinguished statistically between both maltodextrins (Student's t-test, 6.45; $p < 0.01$) showing a media of 0.0607 MPa J^{-1} M150 tablets and 0.0913 MPa J^{-1} M150 tablets. So M150 showed more facility to form compacts, maybe due to its slightly fragmentation or rearragement at the beginning of the compression that results in new areas of excipients without lubricant that can form bonding unions (Muñoz-Ruiz et al., 1993).

3.2. *Effects of the addition of lubricants*

M150 tablets without lubricants, due to its high friction and adhesion, were not possible to obtain under our conditions. For this reason, only M510 tablets have a reference batch (Table 4). The addition of lubricants to M510 leaded to a decrease in the net apparent work (Tables 1–4), but after the subtraction of friction work, we can conclude that these results were due not only to a lower energy required to make the tablets but also to a lower friction (De Blaey and Polderman, 1970; Pilpel, 1971).

However, the comparison of these values of net apparent work after taking into account friction, were no statistically different ($p > 0.05$), maybe because the addition of lubricant implies a decrease in friction but also an increase of expan-

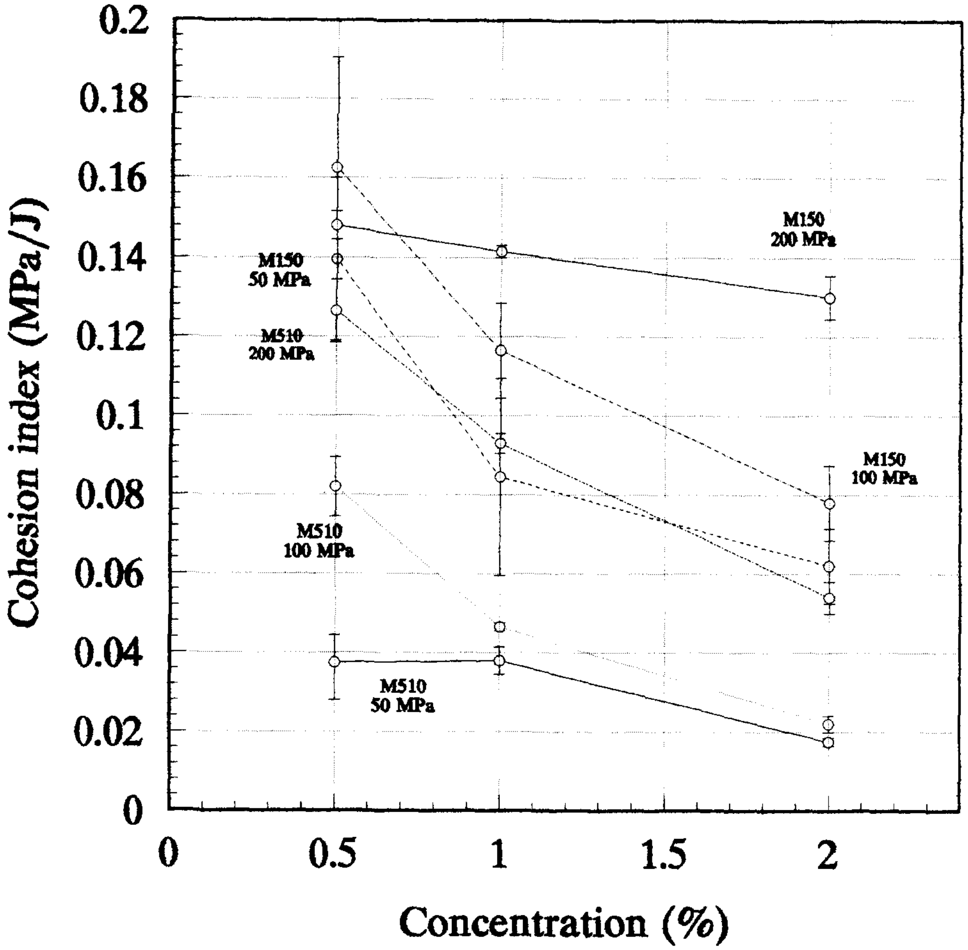

Fig. 1. Cohesion index of maltodextrins at different applied pressures as a function of magnesium stearate concentration.

sion, so the effect was counteracted in the final value of net apparent work.

All the lubricants increased the expansion work which is consistent with the concept that lubricants increase elastic nature of the materials and therefore avoid the accumulation of stresses in the tablet that causes problems as capping (De Blaey and Polderman, 1970).

In summary, in M510 tablets the lowest expansion and friction is presented with PRUV® and by magnesium stearate, therefore these two lubricants showed higher net apparent work than PRECIROL®. On the other hand, M150 showed these results in the formulations containing magnesium stearate.

The cohesion index for tablets containing PRECIROL® showed the lowest value for both maltodextrins (Figs. 1–3), supporting published data (Delacourte et al., 1993). The morphological characteristics of PRECIROL® justify the results. PRECIROL® had the lowest projected area (PRECIROL®, 0.0027 μm^2; PRUV®, 541.9 μm^2; magnesium stearate, 355.1 μm^2) Besides, the mean diameter of this lubricant (0.063 mm) was lower than the one presented by magnesium stearate (23.36 mm) and PRUV® (29.66 mm).

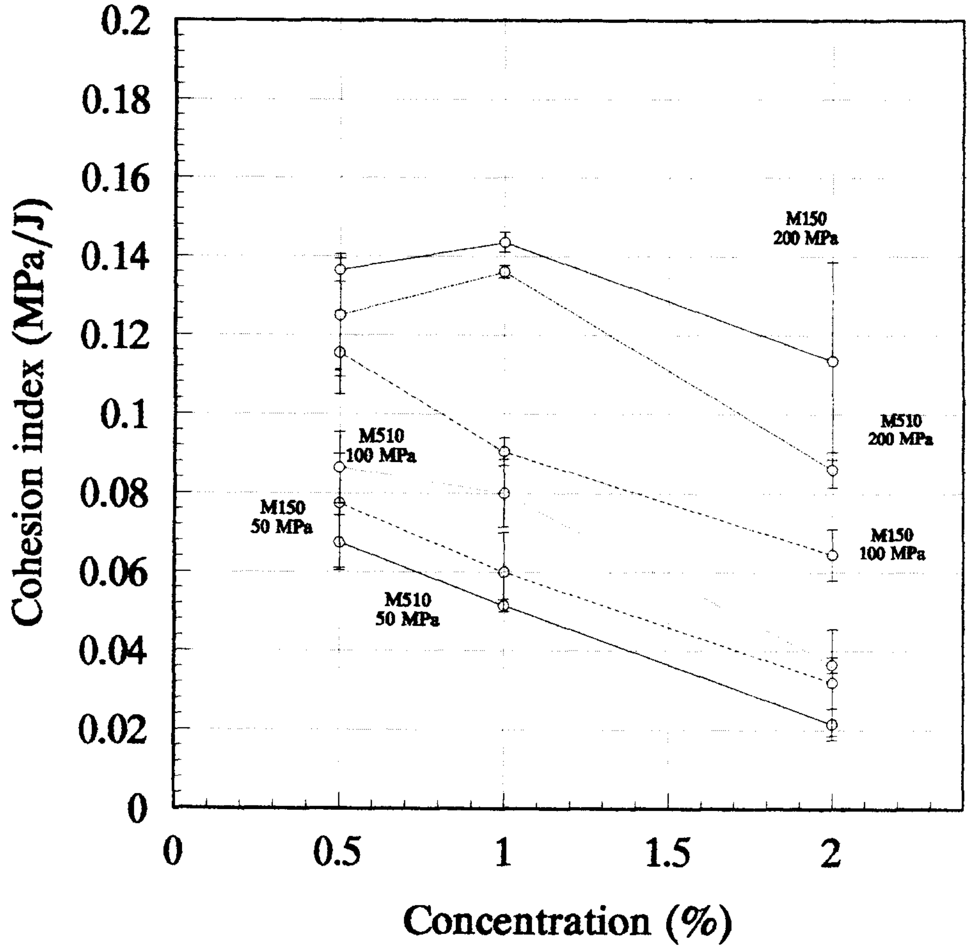

Fig. 2. Cohesion index of maltodextrins at different applied pressures as a function of PRUV® concentration.

These small particles can occupy the places between maltodextrins particles and decrease their bonding properties. Also, the comparison of M510 tablets without lubricants with those elaborated with lubricants showed statistical differences only for PRECIROL® (Student's t-test, 2.42; $p < 0.05$).

Sodium stearyl fumarate showed slightly superior cohesion index in M510, while in M150 the highest value corresponded to magnesium stearate (Figs. 1 and 2). This behaviour can be explained by the different sensitivity to the addition of lubricants showed by both maltodextrins. Thus, the film formation is unlikely to become complete when dealing with poorly flowing powders like M150 (Muñoz-Ruiz et al., 1993).

3.3. Effects of the variables

In magnesium stearate tablets, the conditions for the higher expansion work and less net apparent work were obtained in M510 with 2% and 10 min of mixing time. These results were presented in M150 with the lowest mixing time while no specific trend was observed in relation with concentration, maybe due to its insensitivity. According to the results of PRUV® and PRECIROL®, there could not be established a behaviour with these variables as they did not affect markedly to force-displacement parameters.

Figs. 1–3 represent the cohesion index as function of concentration of lubricants. Magnesium

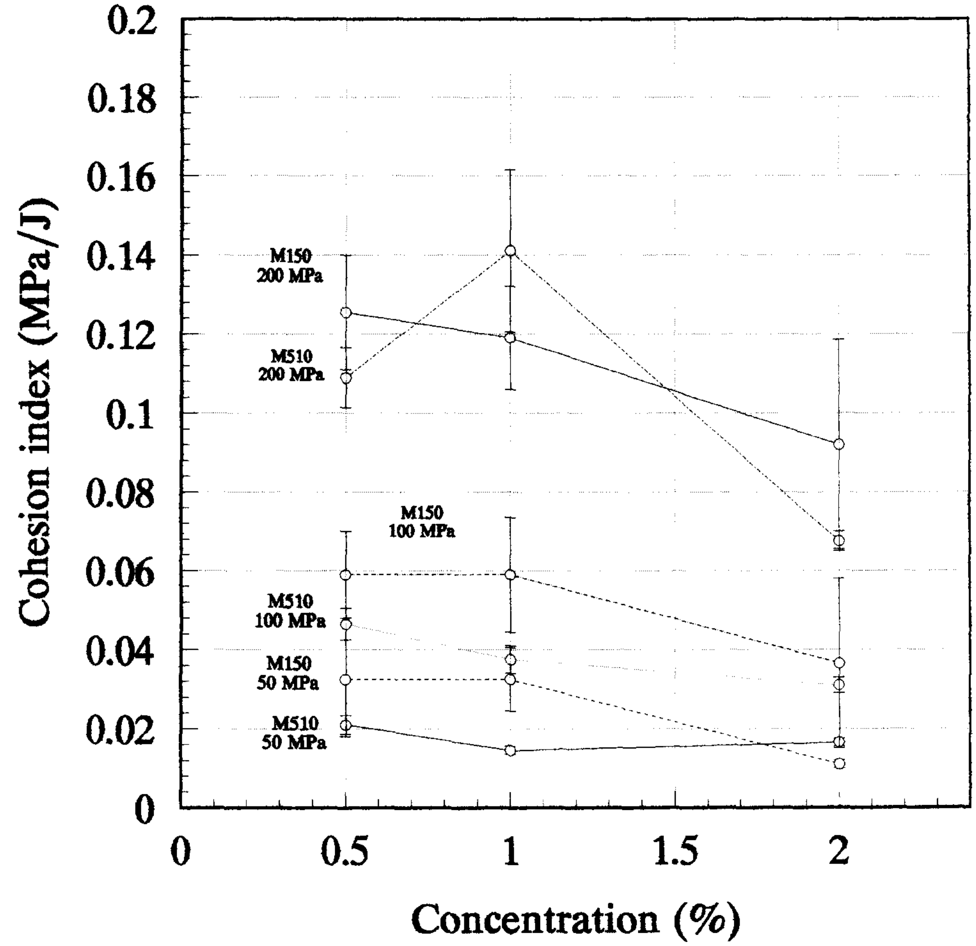

Fig. 3. Cohesion index of maltodextrins at different applied pressures as a function of PRECIROL® concentration.

stearate is known to have strong negative effects on the binding properties of excipents, due to the formation of lubricant film on the particle surface (Vromans et al., 1988). Both maltodextrins showed statistically significant higher cohesion index in the lower concentration and mixing time of magnesium stearate (Fig. 1).

PRUV® due to their morfological properties, without a laminar shear structure, has been reported to be less prone to decrease cohesion between particles. In our study, concentration of this lubricant was statistically significant ($p < 0.05$), obtaining the less value of cohesion index (Fig. 2) at the highest concentration (Lindberg, 1972). Regarding mixing time, cohesion index was significant lower for the highest minutes in M510, however it was not significant in M150, again may be due to its insensitivity to lubricants.

The concentration of PRECIROL® (Fig. 3) was a significant variable on both maltodextrins, while mixing time did not affect due to the structure of this lubricant, constituted by small flakes with high cohesion between them and forming agglomerates which may not delaminate under these mixing time conditions.

In relation with applied pressure, linear regressions with correlation coefficients higher than 0.9 were observed between expansion work and applied pressure, being the expansion higher at the maximum applied pressure.

Table 4
Force-displacement parameters of M510 tablets obtained without lubricants

Applied pressure (MPa)	Expansion work (J)	Net apparent work (J)	Plasticity (%)	Cohesion index (MPa J^{-1})
200	2.086 (0.236)	22.72 (0.92)	91.59 (0.83)	0.111 (0.006)
100	1.054 (0.101)	11.64 (0.14)	91.70 (0.67)	0.074 (0.013)
50	0.478 (0.048)	7.93 (0.34)	94.32 (0.44)	0.042 (0.004)

The net apparent work also increased with the applied pressure, following a linear relation. If the work of friction was considered, the correlation coefficient was improved, being the fit better with Juslin expression.

The higher the work input involved during the compaction of a powder system, the stronger the compact is expected to be formed due to the larger amount of energy utilized in the formation of bonds. Figs. 1–3 show how the cohesion index increased with the applied pressure in both maltodextrins, although there was not a linear relation between both variables.

The formation of an intact compact by compression results due to forces present at the particle-particle contact areas. As the compression pressures are increased, large true contact areas between particles are established. Plastic materials will permanently deforme and create extensive areas of true contact between particles, whereas elastic materials will store energy elastically under compression. During decompression, the stored elastic energy may disrupt and separate the true contact areas that were established by compression forces resulting is poor bonding. These different behaviours can be shown by the same materials depending on the range of applied pressure studied. As we have indicated previously, there was a linear relation between expansion work and applied pressure, however, when the elastic nature was studied in relation with applied work as in plasticity expression, no linear trend was observed. This parameter showed the sequence from minor to maximum 200, 50 and 100 MPa. Over 100 MPa the limit of plastic deformation was found and an increment of applied work did not contribute to the densification of the material, in agreement with the results of Mollan and Çelik (1993).

In conclusion, friction work and cohesion index can be used as parameters to distinguish statiscally between two excipients of the same familly after the addition of lubricants. On the other hand, the effect of the addition of lubricants did not depends only on their properties, but also the excipients characteristics had an important role. Thus, as many factors take place in the final results is necessary to study the appropiate lubricant for each material. Finally, the effect of concentration and mixing time of the lubricants was statistically significant in most of the cases (ANOVA), however the results were not the same for both maltodextrins.

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