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EFFECT OF MOISTURE OF PHARMACEUTICAL MATERIAL MCC AVICEL PH102 AND TABLET DIAMETER ON THE COMPRESSION PROCESS AND TABLET STRENGTH

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Abstract: This paper focuses on the effect of moisture of powder material on the process of tablet compression and on tablet mechanical strength. The powder used in the experiments was Avicel PH102 microcrystalline cellulose, as it is the most widely used excipient in direct tablet compression. The compression process is described using the Heckel equation and the strength of the tablets was determined using a Brazilian test. To introduce the reader to the issue, the first part of the paper is devoted to a theoretical introduction. The second part of the work is devoted to the description of experimental equipment and work procedure. The last part of the paper presents the results of the experiment and their evaluation. The reason for this experiment was the assumption that the moisture of the raw material significantly affects the compression process and the mechanical strength of the tablet. A series of experiments demonstrated this effect, which can be seen in the respective graphs.

KEYWORDS: Heckel equation, Brazilian test, Avicel PH102 microcrystalline cellulose, tableting, powder compression

1 INTRODUCTION

Tableting represents one of the most important unit operations in the pharmaceutical industry because the physical and mechanical properties of the tablets, such as density and mechanical strength, are often significantly affected by this process [7]. It is the process of uniaxial high-pressure compression, by which the raw material is compacted by mechanical pressure. The final product consists of an active substance and an excipient, while the most used excipient in the pharmaceutical industry is microcrystalline cellulose (MCC) [6]. MCC is available in several forms and under several trade names, with the Avicel PH102 being one of the most common types used in direct compression. The process of compression is influenced by several factors that affect the quality of the final product. An important factor is the moisture content of the raw material. The compression process can be described by several mathematical models, while one of the most used models is the one designed by R.W. Heckel [2]. It is also very important that the tablet should have adequate mechanical strength as it must be resistant during packaging and transport. By experiments performed on a suitable device, the optimal properties of the raw material and the compression parameters can be determined in order to produce a product of the desired properties.

2 THEORY

During tableting, the raw material is compressed and compacted. To better understand the compression process, it is necessary to describe this process using a mathematical model.

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One of the most commonly used models created for this purpose is the Heckel equation. Heckel hypothesized that the compression process is analogous to a first-order chemical reaction, where pores are reactants and compacted material is final product [1]. The dependence of the degree of compaction with increasing pressure on the porosity can be expressed by the following equation:

$$\frac{\mathrm{d}\rho_r}{\mathrm{d}P} = k\varepsilon \tag{1}$$

The solution of this differential equation is:

$$\ln\left[\frac{1}{1-\rho_r}\right] = kP + A \tag{2}$$

A graphical representation of this equation can be seen in Figure 1 with the curve divided into four main areas. The part of the curve representing the stage of plastic deformation has a linear course with the slope k and the intercept A.

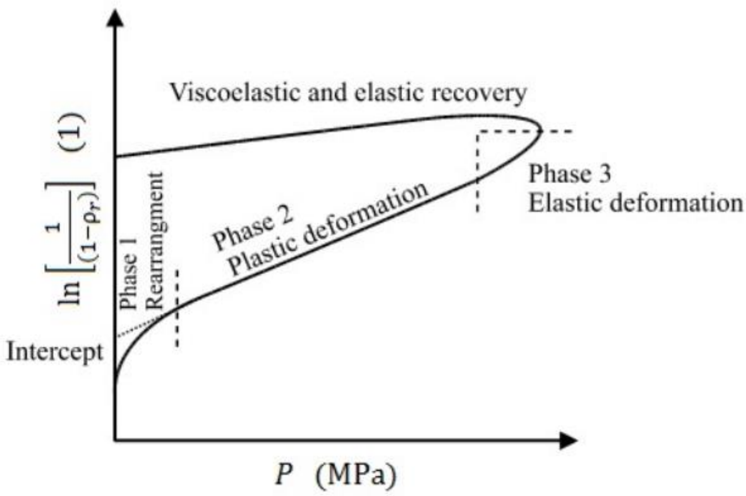


Fig. 1 Typical course of Heckel graph [5]

The inverse value of the slope k is called the yield pressure P_y, which is inversely related to the ability of the material to deform plastically under pressure.

$$P_y = \frac{1}{k} \tag{3}$$

Strength is one of the most important quality parameters of the tablet as a final product. The simple test to determine this property is the radial pressure test, also called the Brazilian test. During this test a radial force is applied to the tablet (Fig. 2), which is increased until a fracture occurs across the tablet. Subsequently, using this force and the dimensions of the tablet under investigation, the tensile strength of the tablet is calculated using an Equation 4.

$$\sigma_T = \frac{2\,F_{max}}{\pi\,D\,H} \tag{4}$$

3 MATERIALS AND METHODS

The material used in the experiment was microcrystalline cellulose Avicel PH102, due its very good flowability, compressibility and compatibility and because its frequently used in the pharmaceutical industry [4]. The examined moisture content of the material ranged from 2,8% to 13,9%.

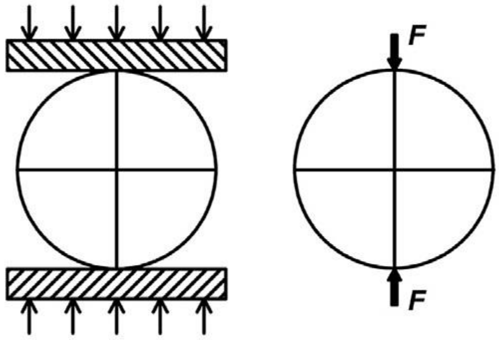
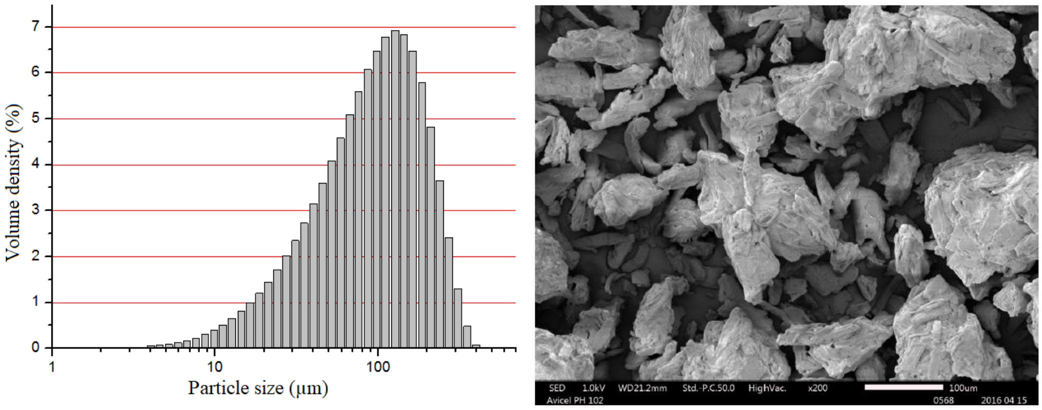
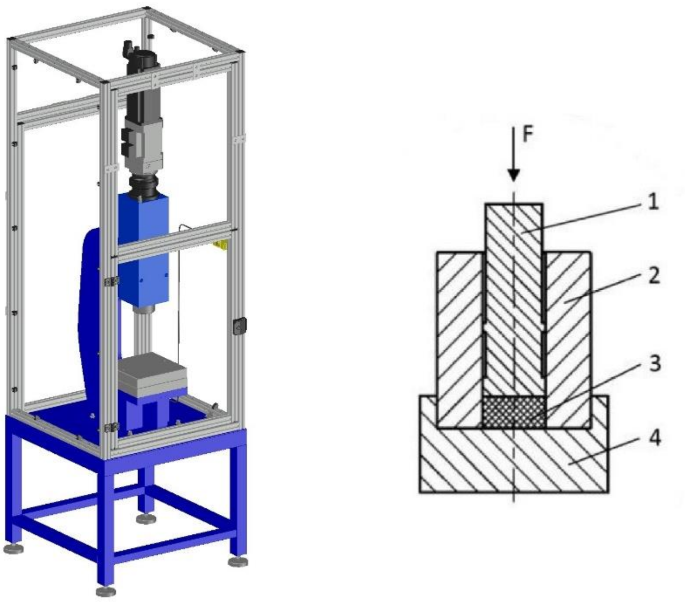


Fig. 2 The principle of the Brazilian test [8]



a) *b)*

Fig. 3 Avicel PH102 microcrystalline cellulose [3,6]
a) particle size distribution; b) image of electron microscopy



a) b)

Fig. 4 Experimental station [6], a) Kistler 2153A electromechanical press; b) tableting die:
1 - compressing punch, 2 - die, 3 - compressing powder, 4 - base of the tableting die

The measurement was performed on a Kistler 2153A electromechanical press (Fig. 4a), which has an integrated punch force sensor and a punch position sensor. The compression of the powder itself took place in a tableting die (Fig. 4b), which was placed in the press. Two tableting dies with a diameter of 13 mm and 20 mm were used for this experiment. The compression pressure used was 130 MPa and the punch speed was 1 mm/s.

At the beginning, samples with a moisture content of 2,8 %, 3,6 %, 5,3 %, 8,8 %, 10,4 %, 13,9 % were prepared. These values were chosen to make the results comparable to previous experiments. The next step was to weigh the required amount of raw material. 4 g of material was used for 20 mm tablets, and 1,1 g of material for 13 mm tablets. Weights were chosen so that tablets of both diameters had the same diameter to height ratio. Subsequently, the tablets were made at the required pressure and compression speed, and their dimensions were measured.

After 24 hours, the tablets were measured again, and a tablet strength test was performed.

4 RESULTS

The influence of the moisture content in the examined material on the behaviour of the powder during compression can be observed in Figure 5. Curves representing a material with a higher moisture content have a more dominant region of particle rearrangement, while a linear region of plastic deformation reaches greater values on the y-axis than curves representing a material with a lower moisture content, which corresponds to the values of yield pressure (Table 2). Tablets made of a material with a lower moisture content have higher yield pressure values than tablets extruded from a material with a higher moisture content. This means that if the same compression pressure is used, the material with a higher moisture content will achieve a greater degree of compaction during the compression process than the material with a lower moisture content. The same behaviour can be observed with both 13 mm and 20 mm tablets.

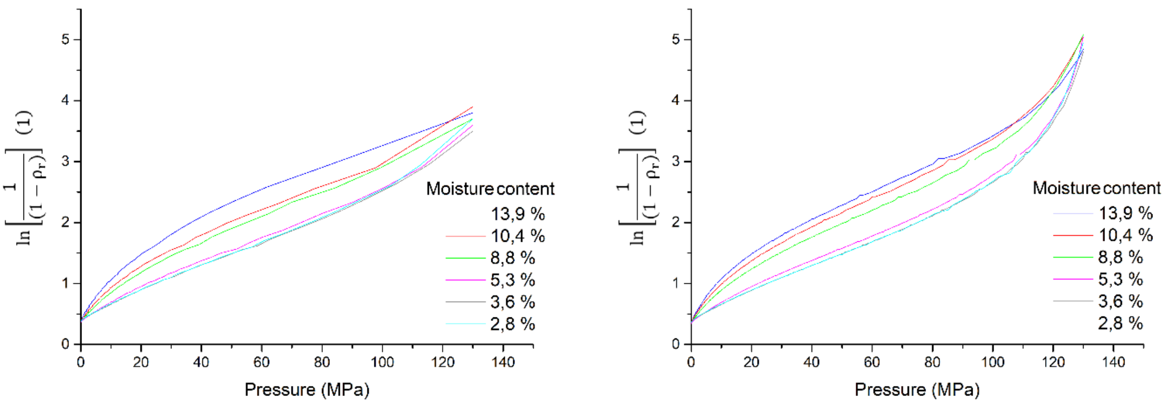


Fig. 5. Heckel graphs for tablets with diameter of 13 mm (left) and for tablets with diameter of 20 mm (right)

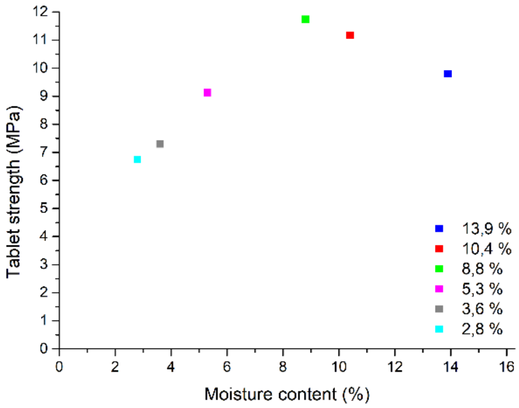
Table 1. Tablet heights [mm]

Moisture content	2,8 %	3,6 %	5,3 %	8,8 %	10,4 %	13,9 %
13 mm tablets	6,53	6,38	6,27	5,66	5,68	5,58
20 mm tablets	10,54	10,50	9,91	9,06	9,04	8,98

Table 2. Yield pressure [MPa]

Moisture content	2,8 %	3,6 %	5,3 %	8,8 %	10,4 %	13,9 %
13 mm tablets	40,95	39,80	39,69	37,42	36,61	35,49
20 mm tablets	38,15	37,83	37,21	33,00	32,36	32,07

According to graph (Fig. 6), the tablet strength increases with increasing moisture content in the raw material, while the maximum value is reached at a moisture value of 8.8 %. A further increase in the moisture content of the raw material causes a loss of tablet strength. The same behaviour can be observed with both 13 mm and 20 mm tablets, while tablets with a smaller diameter achieving higher strength at higher moisture content values. The tablet strength values for each tablet are listed in the Table 3.



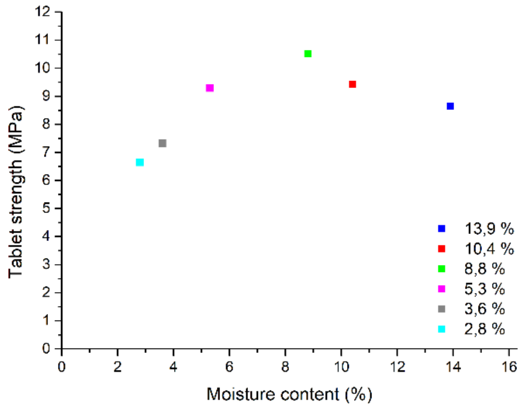


Fig. 6. Dependence of tablet strength on material moisture for tablets with diameter of 13 mm (left) and for tablets with diameter of 20 mm (right)

Table 3. Tablet strength [MPa]

Moisture content	2,8 %	3,6 %	5,3 %	8,8 %	10,4 %	13,9 %
13 mm tablets	6,75	7,30	9,13	11,74	11,17	9,79
20 mm tablets	6,64	7,32	9,29	10,52	9,42	8,64

CONCLUSION

This work described research into the properties influencing the compression process of the common pharmaceutical filler Avicel PH102 in the process of tablet production and the influence of the same properties on the final mechanical strength of tablets. The main investigated property was the moisture content of the raw material. The measured data were evaluated using the Heckel equation and the tablets were subjected to the Brazilian test. Appropriate graphs have been created to better display the required dependencies.

These graphs show that tablets prepared from a material with a higher moisture content achieved a greater degree of compaction than tablets made from a material with a lower moisture content. It has also been proven that smaller tablets achieved higher yield stress values, indicating a lower degree of compaction than larger tablets.

By evaluating the strength test, the optimal moisture value of the material was found to form tablets with the highest possible mechanical strength. It is important that the moisture content of the material should not be too low and the limit value not exceeded. In all cases, the tablets with the highest mechanical strength were made of a material with a moisture content of 8.8%.

This experiment confirmed the general assumptions and the measured data can be used for computer simulations.

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LIST OF SYMBOLS

k	slope of linear course	(Pa^{-1})
A	intercept of linear course	(1)
D	tablet diameter	(m)
F_{max}	fracture force	(N)
H	tablet height	(m)
P	applied pressure	(Pa)
P_y	yield pressure	(Pa)
ε	porosity	(1)
ρ_r	relative density	(1)
σ_T	tensile strength	(Pa)

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