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Compaction pressure, wall friction and surface roughness upon compaction strength of *Andrographis paniculata* tablets

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ABSTRACT

A well-known Malaysian herb, *Andrographis paniculata* was used in this study. This herb is famous at reducing sugar levels for diabetic patients. In this study, the herb was compressed into tablets. A compressed tablet, which is a universal form in modern medicine, needs to meet certain mechanical strength criteria in order to withstand post-compaction loading such as coating, handling, packaging and storage. The objectives of this work were to investigate the effects of compaction pressure, wall friction and surface roughness upon compaction strength of *A. paniculata* herb during compression. A universal testing machine with pressures ranging from 15 to 30 MPa was used to compact the herb using a 20-mm-diameter cylindrical stainless steel uniaxial die. The tensile strength of the tablet increased as the compaction pressure increased. During compression, as the amount of powder being compressed increased, the tensile strength increased, and from the surface roughness test, the coefficient of wall friction and angle of wall friction decreased. In general, the compaction pressure, the wall friction and surface roughness plays a significant role in tabletting; hence, in producing a tough and coherent tablet.

1. Introduction

1.1. *Andrographis paniculata herb*

Andrographis paniculata herb is commonly known as "king of bitters", as it is bitter in taste and it has rather poor odour. The plant is a member of the herb family of Acanthaceae. This is an annual herb and has been widely used in Malaysia and described as "hempedu bumi" and "akar cerita". It is indigenous to Southeast Asia, China and India. The plant can grow very easily, particularly in moist soils.

It has been reported that the plant contains flavones and lactones, and among lactones, Andrographolide is the main constituent of the plant [1]. Commonly, it is well-known in the Asian community to reduce sugar level for diabetes mellitus patients. Further, a few research studies have proved that this herbal extract is useful as an anti-inflammatory, antiviral [2], anticancer and immunostimulatory medicine [3]. The study has also shown the side effects of large doses of *A. paniculata* may cause gastric discomfort, vomiting and loss of appetite [4]. It can also have contraceptive effects in mice and abortifacient effects in pregnant rabbits when they are fed with this herb [4]. Although a similar effect has not been observed in humans, *A. paniculata* should not be taken during pregnancy or by women trying to conceive.

At present, most *A. paniculata* products available in the market are in the form of a crude dried powder from leaves and stems. The modification of the powder preparations in the form of capsules or tablet containing standardized doses of the extract will improve the quality of the products.

1.2. *Compression*

In a typical pharmaceutical industry, compression is one of the most important key of unit operations in developing solid oral dosage forms. It is the simplest way of combining the ingredients which can be blended and placed into a die and compressed to make a tablet without any of ingredients having to be changed. Nonetheless, the wall friction between the tablet and the die wall is one of the important factors in tabletting processes of powders. The inter-particle and particle or wall friction hinders pressure transmissions and therefore produces density gradients inside the compact [5]. Thus, causes non-uniform packing densities within the tablet. High wall friction creates high stress gradients within the block, and hence causing significant density fluctuation [6].

Wall friction will also leads to variations of surface roughness values of the compressed tablet surfaces. In the pharmaceutical industry for instance, surface roughness influences particle flow properties, wettability, surface friability and the quality of the

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final tablet coating. In tribology, wall friction is described to be governed by three groups; the bulk solid and wall surface characteristics, as well as loading and environmental factors [7].

In this paper, the compression characteristics of *A. paniculata* herb were investigated. The wall friction was measured via an indirect method and the data were incorporated into Janssen–Walker's equation [5] and the surface roughness was measured.

1.3. Compression characteristics

One of the most commonly used equations to evaluate compression characteristics is the Kawakita and Lüdde equation [8] and it has been widely used in the pharmaceutical industry, particularly for soft and fluffy powders [8]. The following is its linear relationship [8]:

$$\frac{P}{C} = \frac{1}{ab} + \frac{P}{a} \tag{1}$$

where

$$C = \frac{V_0 - V}{V_0} = \frac{abP}{1 + bP} \tag{2}$$

where P is the compaction pressure (MPa), V_0 the initial apparent volume (m^3), V the powder volume under applied pressure (m^3) and a, b the constants. C is the degree of volume reduction, and it is proportional to the packing properties of the particles [8].

1.4. Wall friction

The wall friction F_w during powder compression can be determined from the normal force F_a and the transmitted force F_T [9] as

$$F_w = F_a - F_T \tag{3}$$

The coefficient of wall friction μ, [5] can be determined using the following equation:

$$\ln\frac{\sigma_b}{\sigma_a} = -4\mu K_W F_D\left(\frac{H}{D}\right) \tag{4}$$

where σ_b is the transmitted stress at the bottom punch (MPa), σ_a normal stress on the upper punch (MPa), D the diameter of the die (m) and H the height of the tablet (m). K_w represents the ratio between the radial and axial stress during compaction. Though, the accurate definition of K_w is rather ambiguous [5]. K_w is assumed constant based on Jenike and Johanson [10] for most particulate materials as 0.4. F_D is the distribution factor that depends on the ratio of the normal and transmitted stresses. It can be calculated when the transmitted stress reached an asymptotic value and for many systems, it has been considered as being close to unity [5], particularly for ceramic powders which has a viscoelastic property. In the current context of herb powder, which is also having viscoelastic properties, F_D is also assumed as 1.0.

Thus, the angle of wall friction, φ_w can be calculated as

$$\mu = \tan\varphi_w \tag{5}$$

where μ is the coefficient of wall friction.

1.5. Surface roughness

Surface roughness is usually measured as a summation of negative and positive deviations from a 'mean plane' fit over the surface of interest. Typical parameter for surface roughness is defined below in the following relations [11]:

$$R_a = \frac{1}{L}\int_0^L |m(n)|dn \tag{6}$$

where R_a is the arithmetic average surface roughness, or average deviation, m the height of the surface above the mean line at a distance (m), n from the origin and L the overall length of the profile under examination (m).

2. Experimental details

2.1. Materials

The herb, *A. paniculata* powder was obtained from Ya'acob Berkat Enterprise, Melaka, *Malaysia.* (Ya'acob Berkat Enterprise, Melaka). The powder was produced by grinding dried leaves. Fig. 1 shows the *A. paniculata* plant. The material properties on the herbs used are shown in Table 1 and the scanning electron microscopy (SEM) images is shown in Fig. 2 (a) and (b), at 200 and 1000 times magnifications.

Fig. 1. *A. paniculata* plant.

Table 1
Material properties of *A. paniculata*.

Material properties	Values
Mean particle size (μm)	181.3
Bulk density, ρ_b (kg/m3)	302.3
Tapped density, ρ_t (kg/m3)	363.5
Moisture content (oven) (%)	9.4
Moisture content (digital) (%)	8.6
Carr index, CI (%) [12]	16.8
Hausner's ratio, HR [13]	1.2
Flowability [12,13]	Medium flow