In recent years, interest in excipients derived from natural polysaccharides among the researchers is growing because of their biodegradability, low cost, minimal toxicity profile and availability (1, 2). Polysaccharides are a class of carbohydrate with long chains of monosaccharide and one of the examples is starch (3). Starch is commonly used as an excipient in the production of solid formulations and today, starches extracted from various sources have been studied and utilized either as a binder or disintegrant in the form of mucilage or dry powder (4, 5). Binder is an excipient that produces cohesiveness to the powder mixture and to allow the tablet to remain intact after compression whereas disintegrant is the excipient that can result in the disintegration of the tablets and drug release on contact with moisture (4-6).

There are some researches done on the pharmaceutical excipient behavior, including binding and disintegrant properties of starches extracted from various sources. For instance, binding properties of ginger starch and tapioca sago starch were found to be as effective as gelatin in paracetamol tablets (7, 8). Binding property of tapioca starch was also found to be comparable to those of crospovidone, croscarmellose sodium and sodium starch glycolate. Flow property of chickpea starch was assessed with the measurement of bulk density, tapped density, compressibility index and angle of repose. Calibration curve for gliclazide in phosphate buffer pH 7.4 was developed. Gliclazide IR tablets were then produced with direct compression method. Physicochemical characteristics of the tablets, including thickness, tablet weight uniformity, hardness, disintegration time and friability were evaluated. Then, in vitro dissolution studies were performed by following United States Pharmacopeia (USP) dissolution method. The dissolution results were analyzed and compared with t30, t50, dissolution efficiency (DE). Lastly, drug-excipient compatibility studies, including Fourier transform infrared (FTIR) spectroscopic analysis and differential scanning calorimetric (DSC) analysis were carried out. Fair flow property was observed in the chickpea starch powder. Furthermore, the tablets produced passed all the tests in physicochemical characteristics evaluation except hardness and disintegration test. Additionally, in vitro dissolution studies show that chickpea starch acted as a disintegrant instead of a binder in gliclazide IR tablets and its disintegrant properties were comparable to those of crospovidone, croscarmellose sodium and sodium starch glycolate. Besides that, gliclazide was also compatible with the excipients used. Chickpea starch acted as a disintegrant in gliclazide IR tablets, instead of a binder. Therefore, chickpea starch can be a promising disintegrant in gliclazide IR tablets.

Keywords: chickpea starch, gliclazide, binder, disintegrant
Chickpea (*Cicer arietinum*) is a type of edible legume under the family of Fabaceae and subfamily of Faboideae (11). It can be further classified into desi and kabuli chickpea (12). Desi chickpea is characterized by thick seed coat with a rough surface, whereas kabuli chickpea has a thin seed coat with a smooth surface (12). Researches show that carbohydrate in the chickpea was between 50.7 and 66.9% and around 43 to 56% of the carbohydrate was starch (13, 14). This is further supported by the results of pure starch yield of 32.4% to 35.9% from chickpea in the study by Hughes et al (11). Therefore, these researches show that large amount of starch is present in chickpea. Since starch is widely used as an excipient in various formulations, pharmaceutical excipient behavior of chickpea starch was investigated in this study and its binding property was compared with that of povidone and its disintegrant property was compared with those of three superdisintegrants, including crospovidone, croscarmellose sodium and sodium starch glycolate. Luis Fernando et al. had done the research on composition and physicochemical, structural and functional characteristics of chickpea starch. The chickpea starch showed large oval shaped granules and small spherical shaped ones, all with a smooth surface. They concluded that chickpea starch is interesting for use in foods requiring hot viscosity. There are no other reported works on chickpea starch as a pharmaceutical excipient (15).

Gliclazide is a short-acting oral hypoglycemic agent under the class of sulfonylurea (16). It is mainly used for type 2 diabetes mellitus to increase the insulin secretion from pancreatic beta cells. Up to this time, no research has been done on excipients derived from natural polysaccharide in gliclazide formulation. Therefore, the research objectives are to characterise the chickpea starch powder and to evaluate the pharmaceutical excipient behavior of this starch in gliclazide immediate release tablets.

**EXPERIMENTAL**

**Materials**

Chickpea starch was extracted in research lab, International Medical University, Malaysia. Gliclazide, povidone, lactose, magnesium stearate, talc, sodium hydroxide, potassium dihydrogen phosphate and potassium bromide were purchased from Labchem Sdn. Bhd., Malaysia. Crospovidone, croscarmellose sodium and sodium starch glycolate were received as free samples from Dr. Reddy’s Laboratories Ltd., India. All chemicals were obtained from the manufacturers and utilized with-

<table>
<thead>
<tr>
<th>Formulation</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>97.0</td>
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</table>
out further purification. Additionally, all chemicals used in this research were of laboratory grade.

Characterization of chickpea starch powder

**Bulk and tapped densities**

Ten grams of chickpea starch powder was weighed and loaded into a graduated cylinder. Then, the volume was read and recorded as bulk volume (2). The cylinder was then tapped on a flat platform until a constant volume was achieved and this was recorded as tapped volume. These tests were repeated for another two times. Then, bulk density (BD), tapped density (TD), and compressibility index were computed with the formulae as shown below (2, 17).

\[
\text{BD} = \frac{\text{mass}}{\text{bulk volume}} \quad (1)
\]

\[
\text{TD} = \frac{\text{mass}}{\text{tapped volume}} \quad (2)
\]

\[
\text{Compressibility index} = \frac{(\text{TD} - \text{BD})100}{\text{TD}} \quad (3)
\]

**Angle of repose**

Ten grams of chickpea starch powder was filled into a plugged glass funnel with a 10 cm distance from the flat surface (8). Cotton plug was removed from the funnel orifice and the powder was allowed to flow. The height of the heap formed (h) and the radius of the heap (r) were measured and recorded. This test was then repeated for another two times. Then, the angle of repose (θ) was computed as:

\[
\theta = \tan^{-1} \frac{h}{r}. \quad (4)
\]

**Calibration curve development for gliclazide**

A stock solution of 50 µg/mL gliclazide was produced by dissolving 5 mg gliclazide in 100 mL phosphate buffer pH 7.4. The stock solution was diluted to 25 µg/mL. Then, 25 and 50 µg/mL solution were scanned with an ultraviolet (UV)–visible spectrophotometer (Perkin Elmer double beam UV-Vis spectrophotometer, Perkin Elmer, USA) to obtain the wavelength with the maximum absorbance (λ_max). Next, 50 µg/mL stock solution was diluted to obtain 5, 10, 15, 20, 25 µg/mL gliclazide solution and the absorbance was measured at λ_max, obtained with the UV-visible spectrophotometer (4). A graph of absorbance versus concentration was plotted and linear equation was obtained.

**Formulation of gliclazide immediate release tablets**

As shown in Table 1, gliclazide immediate release tablets were produced by direct compression technique with 10 and 20% w/w of chickpea starch, povidone, crospovidone, croscarmellose sodium and sodium starch glycolate, respectively (18, 19). All ingredients except magnesium stearate and talc were sieved with sieve no. 35 and mixed vigorously in a sealed poly bag. Magnesium stearate and talc were then added and mixed gently. The tablets were compressed in 10-station tableting machine using 8 mm punch. (Rimek-I rotary tablet press, Karnavati Eng Ltd., India).

Tablet physicochemical characteristics evaluation

**Thickness test**

Vernier calliper was used to measure the thickness of 10 tablets randomly from each formulation and the mean thickness was calculated (9). Then, percentage deviations were determined.

**Uniformity of weight test**

Twenty tablets from each formulation were weighed randomly. Then, average mass was calculated and these tablets were weighed individually (20). The percentage deviations from the average mass were then calculated.

**Hardness test**

Hardness of the tablets produced was measured by using Monsanto hardness tester (Campbell Electronics, India) in 10 tablets randomly from each formulation and average hardness was then calculated (18).

**Disintegration test**

Six tablets from each formulation were placed in basket-rack assembly and the medium used was distilled water at 37 ± 0.5°C (Guoming disintegrator, BJ2, Tianjin). Disintegration time in which the tablets disintegrated and broke into smaller particles that can pass through the wire mesh was recorded (9, 20).

**Friability test**

Twenty tablets were weighed and placed in the tablet friability apparatus (Mettler Toledo, Model: AB 204-S, Switzerland) (21). The apparatus was used at 25 ± 1 rpm and 100 times rotations. The tablets were dedusted and weighed again after the test.

\[
\text{Percent weight loss} = \left( \frac{W_A - W_B}{W_A} \right) 100 \quad (5)
\]

where \(W_A\) is the initial tablet weight whereas \(W_B\) is the final tablet weight.

**In vitro dissolution studies**

In vitro dissolution studies were performed for 1 hour by following United States Pharmacopeia (USP) dissolution method with the use of apparatus II (paddle type) (Electrolab, India) (18, 22). The medium used was 900 mL phosphate buffer with pH
7.4 at 37 ± 0.5°C and the paddle speed utilized was 100 revolutions per minute. 5 mL sample was withdrawn and replaced with buffer at 5, 10, 20, 30, 45 and 60 minutes. The absorbance of the sample was measured spectrophotometrically at the λ_{max} obtained and percentage of drug dissolved was then determined.

**Comparison of dissolution data**

Times t_{30} and t_{50}, which indicate the time taken to reach 30% and 50% of drug release, respectively, were determined and compared between the dissolution profiles (7). Furthermore, model independent technique, including dissolution efficiency (DE) was used for the comparison of drug release from different formulation (23). DE indicates the area under the dissolution profile within a specific duration that is represented as a percentage of the dissolution profile at maximum dissolution within the same duration and it was calculated as:

\[
DE = \frac{\int_{t_1}^{t_2} y \cdot dt}{y_{100} \times (t_2 - t_1)} \times 100
\]

where y is the percentage of drug dissolved at time t.

**Drug-excipient compatibility studies**

*Fourier transform infrared (FTIR) spectroscopic analysis*

The sample was pulverized and mixed completely with potassium bromide (KBr) with the ratio of 1 : 5. Then, this powder mix was compressed into a KBr disc and FTIR spectra were recorded at the resolution of 4 cm\(^{-1}\) from 400 to 4000 cm\(^{-1}\) with the use of Shimadzu FTIR spectrophotometer (Shimadzu, FTIR 8700, Kyoto, Japan) (24).

**RESULTS AND DISCUSSION**

**Characterization of chickpea starch powder**

*Bulk and tapped densities*

The flow property of chickpea starch powder was assessed with the calculation of compressibility index (CI) from bulk and tapped densities (2, 17). The average CI of chickpea starch powder was 19.015% and this result shows that chickpea starch powder possessed a fair flowing nature with CI of 16-20%. This was because starch powder is non-free flowing and has a low interparticulate friction (4). Hence, lubricant such as magnesium stearate and glidant such as talc were incorporated into the powder mixture to improve the flow properties.

*Angle of repose*

Flow property of chickpea starch was further assessed with angle of repose (8). The average angle of repose obtained for chickpea starch powder was 38.967° and this matches with the result obtained for CI in which chickpea starch powder had a fair flowing nature with the angle of repose of 36-40° (17).

*Calibration curve development for gliclazide*

In the calibration curve development, the λ_{max} obtained for gliclazide in phosphate buffer pH 7.4

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Thickness (mm) (± SD) (n = 10)</th>
<th>Weight (mg) (± SD) (n = 20)</th>
<th>Hardness (kg/cm(^2)) (± SD) (n = 10)</th>
<th>Disintegration time (s) (± SD) (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.16 ± 0.08</td>
<td>147.5 ± 6.5</td>
<td>3.21 ± 0.27</td>
<td>989.0 ± 0.1</td>
</tr>
<tr>
<td>2</td>
<td>2.23 ± 0.06</td>
<td>150.0 ± 0.4</td>
<td>3.79 ± 0.32</td>
<td>22.0 ± 1.4</td>
</tr>
<tr>
<td>3</td>
<td>2.21 ± 0.01</td>
<td>152.0 ± 7.1</td>
<td>3.16 ± 0.30</td>
<td>17.0 ± 0.1</td>
</tr>
<tr>
<td>4</td>
<td>2.26 ± 0.01</td>
<td>149.1 ± 1.4</td>
<td>4.00 ± 1.47</td>
<td>634.0 ± 0.1</td>
</tr>
<tr>
<td>5</td>
<td>2.30 ± 0.01</td>
<td>150.6 ± 0.8</td>
<td>4.01 ± 0.80</td>
<td>801.0 ± 0.1</td>
</tr>
<tr>
<td>6</td>
<td>2.31 ± 0.01</td>
<td>149.3 ± 0.7</td>
<td>3.67 ± 0.70</td>
<td>9.5 ± 0.7</td>
</tr>
<tr>
<td>7</td>
<td>2.45 ± 0.01</td>
<td>150.1 ± 0.5</td>
<td>3.93 ± 0.59</td>
<td>25.0 ± 1.4</td>
</tr>
<tr>
<td>8</td>
<td>2.22 ± 0.01</td>
<td>150.2 ± 0.4</td>
<td>3.75 ± 0.46</td>
<td>25.5 ± 0.7</td>
</tr>
<tr>
<td>9</td>
<td>2.22 ± 0.03</td>
<td>150.3 ± 1.0</td>
<td>3.89 ± 0.61</td>
<td>53.0 ± 4.2</td>
</tr>
<tr>
<td>10</td>
<td>2.18 ± 0.03</td>
<td>149.4 ± 2.1</td>
<td>3.90 ± 1.11</td>
<td>16.0 ± 0.1</td>
</tr>
<tr>
<td>11</td>
<td>2.21 ± 0.01</td>
<td>150.7 ± 0.2</td>
<td>3.70 ± 0.25</td>
<td>20.5 ± 2.1</td>
</tr>
</tbody>
</table>
was 226 nm and this matches with the one used by Smita et al. (24) Then, standard calibration curve was plotted against concentration vs. absorbance. The concentration of gliclazide was calculated with the formula:
\[
\text{concentration} = \frac{(\text{absorbance} - 0.0076)}{0.0363}.
\]

**Table 3.** $t_{30}$, $t_{50}$ and dissolution efficiency (DE) of gliclazide formulations.

<table>
<thead>
<tr>
<th></th>
<th>$t_{30}$ (min)</th>
<th>$t_{50}$ (min)</th>
<th>DE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-2</td>
<td>1.50</td>
<td>4.50</td>
<td>91.272</td>
</tr>
<tr>
<td>F-3</td>
<td>1.75</td>
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<td>92.960</td>
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</tr>
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<td>2.50</td>
<td>93.198</td>
</tr>
<tr>
<td>F-11</td>
<td>1.50</td>
<td>2.50</td>
<td>94.295</td>
</tr>
</tbody>
</table>

**Tablet physicochemical characteristics evaluation**

Physicochemical characteristics of the gliclazide immediate release tablets produced were then assessed to ensure that the tablets produced complied with the standard pharmacopoeial limits.

**Thickness test**

As shown in Table 2, the thickness of the tablets varied from 2.16 ± 0.08 mm to 2.45 ± 0.01 mm. The thickness of all formulations was within ±5% of the average thickness values and all formulations passed the thickness test.

![Figure 1. Effect of different concentration of chickpea starch (CS) as a disintegrant on the average percentage of drug dissolved](image1)

![Figure 2. Comparison of pharmaceutical excipient behavior of CS and PV (15 mg)](image2)
Uniformity of weight test
The tablet weight ranged from 147.5 ± 6.5 mg to 152.0 ± 7.1 mg. The weight of all formulations was within ±7.5% of the average weight values and therefore, all formulations passed this test (18).

Hardness test
The tablet hardness was in the range of 3.16 ± 0.30 kg/cm² to 4.01 ± 0.80 kg/cm². From the results it was observed that chickpea based formulations are having enough strength.

Disintegration test
The disintegration time of the tablets was between 9.5 ± 0.7 s and 989.0 ± 0.1 s. All formulations disintegrated completely within 15 minutes and passed this test except Formulation 1 because this formulation did not contain chickpea starch and any other superdisintegrants (20). Besides that, through the disintegration time for Formulation 1 to 3, chickpea starch showed disintegrant properties instead of binding properties because disintegration time decreased with the increasing concentration of chickpea starch (5). From the results, it was observed that chickpea is strongly producing disintegration properties.

Friability test
For friability test which was done for all the formulations it was found that the weight loss obtained was less than 0.99% for all the formulations. Hence, this indicates that the formulation made with chickpea starch possessed adequate mechanical strength to resist against tablet fracture and abrasion.

In vitro dissolution studies
Chickpea starch acted as a disintegrant
For in vitro dissolution studies, the effect of different amount of chickpea starch on the average percentage of drug dissolved was studied. As shown

![Figure 3. Comparison of pharmaceutical excipient behavior of CS and PV (30 mg)](image)

![Figure 4. Comparison of disintegrant properties of chickpea starch (CS) and 3 superdisintegrants (CPV, CCS, SSG) (15 mg)](image)
in Figure 1, since the presence of chickpea starch resulted in an increase in the average percentage of drug dissolved, this indicates that chickpea starch acted as a disintegrant instead of a binder (5). Additionally, for t₃₅₅, t₅₀, and DE, the p-value of the t-test obtained was 0.001, which was less than 0.05 and this signifies that there was a significant difference in terms of average percentage of drug dis-
solved between Formulation 1 (without chickpea starch) and 2 (with chickpea starch).

**Comparison of pharmaceutical excipient behavior of chickpea starch (CS) and povidone (PV)**

Pharmaceutical excipient behavior of chickpea starch was then compared with that of povidone. Based on Figure 2 and 3, chickpea starch did not exhibit binding property like what povidone did because average percentage of drug dissolved increased with increasing amount of chickpea starch. This shows that chickpea starch behaved as a disintegrant in gliclazide immediate release tablets. However, average percentage of drug dissolved decreased with the increasing amount of povidone and this shows the characteristic of povidone being a binder that can enhance the mechanical strength of the tablet and slow the dissolution rate.

**Comparison of disintegrant properties of chickpea starch (CS) and 3 superdisintegrants (crospovidone (CPV), croscarmellose sodium (CCS), sodium starch glycolate (SSG))**

Disintegrant property of chickpea starch was then compared with those of crospovidone, croscarmellose sodium and sodium starch glycolate. As shown in Figure 4 and 5, for Formulation 2, 3 and 6 to 11.85% of the drug dissolved within 15 min. According to Food and Drug Administration (FDA), dissolution profiles can be accepted as similar without further statistical analysis if more than 85% of drug release within 15 min (25). This implies that disintegrant properties of chickpea starch was comparable to those of crospovidone, croscarmellose sodium and sodium starch glycolate in gliclazide immediate release tablets. The best disintegrant

Furthermore, the best disintegrant was selected by comparing the t<sub>30</sub>, t<sub>50</sub> and DE of the formulations. Based on Table 3, Formulation 7 was the best formulation in this study with 30 mg of crospovidone and this matches with the result by Gill et al. in which crospovidone was the best superdisintegrant compared to croscarmellose sodium and sodium starch glycolate (18). Overall, all formulations passed the dissolution test in which at least 70% of drug dissolved in solution after 30 minutes except Formulation 1, 4 and 5. This was because Formulation 1 did not contain chickpea starch and superdisintegrant whereas Formulation 4 and 5 contained high concentration of povidone, which slowed down the drug dissolution rate.

![Figure 7. DSC thermograms of gliclazide, chickpea starch and powder mixture](image-url)
Drug-excipient compatibility studies

**FTIR spectroscopic analysis**

For drug-excipient compatibility studies, FTIR spectroscopic analysis was applied in this research to evaluate the interaction between the drug and the excipient (18). As shown in Figure 6, same characteristic peaks for S=O (1165 cm⁻¹), C=O (1709 cm⁻¹) and N-H (3273 cm⁻¹) functional groups were obtained for gliclazide and the powder mixture. This indicates that gliclazide was compatible with the excipients used including chickpea starch because there was no major interaction between the functional groups of gliclazide with the excipients used (26).

**DSC analysis**

Based on Figure 7, a single endotherm corresponding to the melting of gliclazide was shown in the DSC thermogram at 170.16°C. Furthermore, chickpea starch showed a broad peak at 83.68°C. As shown in Figure 7, gliclazide melting peak was completely absent in the mixture DSC thermogram. This was because gliclazide was completely soluble in the melted polymer and it can also be due to the absence of the crystalline nature of gliclazide (24).

Overall, because of time and financial constraints, toxicology and stability studies were not carried out in this research and these studies can be considered to be carried out in the future.

**CONCLUSION**

In conclusion, chickpea starch acted as a disintegrant in gliclazide immediate release tablets. Hence, the alternative hypothesis was accepted in which chickpea starch had pharmaceutical excipient behavior in gliclazide immediate release tablets. Therefore, in the future, toxicology and stability studies can be performed to allow the safe use of chickpea starch as a natural disintegrant.

**Acknowledgment**

Authors are thankful to International Medical University (IMU), Malaysia for providing financial support and research facilities to carry out the present research (Project ID- BP I-01/11(18)2014). One of the authors, M.V.Srikanth, is thankful to Prof. K V Ramana Murthy for providing valuable information to carry out the research work.

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