INTRODUCTION

Peroral drug delivery was the most commonly used and convenient to deliver the drug because it is the most natural, not harmful, easy to use, and safe in terms of drug delivery [1]. To certain people, the use of conventional tablets has caused trouble, such as the elderly who are experiencing difficulties in using conventional dosage forms because of hand tremors and dysphagia [1, 2]. This condition produces non-compliance in a specified group of patients, especially geriatric. Statistics showed that approximately 50% of patients on long-term therapy did not comply with the prescribed treatment [3]. The outcomes from previous work revealed that the cost of treatment, discomfort with treatment, and long-term therapy were common reasons for non-compliance [4]. To overcome these problems, an effective drug delivery system is needed to provide a solution to the non-compliance issues. The orally disintegrating tablet is one of the peroral delivery systems which can exhibit improvement in compliance, especially in geriatric patients who take long-term therapy.

Orally disintegrating tablets are solid single-unit dosage forms that are designed to be placed in the mouth, allowed to disperse or dissolve in the saliva, and then swallowed without the aid of additional water. Orally disintegrating tablets must disperse or dissolve in the mouth quickly, within seconds [5]. US FDA stated that orally disintegrating tablet is a tablet which disintegrates in the oral cavity less than 30 seconds [6]. Orally disintegrating tablets also provide fast disintegration of the tablets results in a quick dissolution of the drug and fast absorption that provide rapid onset of action [7, 8]. The drug may get absorbed from the pharynx and esophagus or from other sections of GIT as the saliva travels down. In such cases, bioavailability is significantly greater than that observed from conventional tablet dosage form [9, 10].

The candidate drug categories for orally disintegrating tablets are diverse, such as cardiovascular drugs used for chronic conditions with a large geriatric population as users [5]. Atenolol is classified as β1-blocker and widely prescribed in diverse cardiovascular diseases such as hypertension, angina, arrhythmias, and myocardial infarction [11, 12]. Atenolol is slightly soluble in water. The solubility of atenolol in water (25 °C) is approximately 13.3 mg/ml [13, 14]. Consequently, in order to increase the solubility and dissolution rate of atenolol, inclusion complex formation with cyclodextrin becomes imperative [15]. β-cyclodextrin as host molecules can interact with various drugs through the ability to entrap low solubility drugs in the hydrophobic cavity. Moreover, the exterior part of β-cyclodextrin which relatively hydrophilic can enhance the solubility of the drugs.

Formulation of orally disintegrating tablets also can enhance the dissolution of atenolol, because it can produce faster disintegration time compare to the conventional tablets. Superdisintegrants are the class of compounds which primarily aid the rapid disintegration of orally disintegrating tablets in the oral cavity [16]. Superdisintegrants are strongly hygroscopic materials that aid in wicking water from the saliva into the internal structure of the tablets. Nevertheless, the hygroscopicity of superdisintegrants is such that both their functionality and tablet stability can be compromised by excessive exposure to high humidity [5]. Hence, in the orally disintegrating tablets formulation, there is a need to have superdisintegrants with low or no moisture sensitivity and rapid disintegration ability. One approach for improving the characteristics of superdisintegrants is co-processing of two superdisintegrants [17]. Crospovidone and sodium starch glycolate were chosen for this study because of their valuable characteristics. Crospovidone had high capillary activity, pronounced hydration capacity and little tendency to produce gels. Sodium starch glycolate was chosen because of its high swelling capacity [5]. The aim of this study was to formulate and evaluate the characteristics of atenolol-β-cyclodextrin using co-processed crospovidone-sodium starch glycolate in increase water uptake, shorten the wetting time,
and thereby decrease the disintegration time of the tablets by synergism effect of these two superdisintegrants and increased the dissolution efficiency.

MATERIALS AND METHODS

Materials

Materials that were used in this study consists of atenolol p. g (Refarmed Chemicals, Lugano Switzerland), β-cyclodextrin (Roquette, France), crospovidone (Kollidon® CL) p. g (BASF South East Asia Pre-Ltd), sodium starch glycolate p. g (Yung Zip Chemical IND. Co. LTD), magnesium stearate p. g (Ajinomoto Co. Inc.), aqua demineralization (Laboratorium of qualitative chemistry, University of Surabaya), mannitol DC p. g (Roth), sodium dihydrogen phosphate p. a (Merck), disodium hydrogen phosphate a (Na2HPO4.12H2O) p. a, sodium acetate trihydrate p. a (Riedel), glacial acetic acid p. a (Merck), methanol pro-HPLC (Mallinckrodt Chemicals), Avicel PH 102p. g (Mingtai Chemical Co. LTD), talc (PT. Brataco), and Whatman filter paper no 41.

Methods

Preparation of inclusion complex of atenolol-β-cyclodextrin

Inclusion complex of atenolol-β-cyclodextrin was prepared by a solvent evaporation method. A mixture of atenolol and β-cyclodextrin were dissolved separately in ethanol; then the dispersion was mixed thoroughly with magnetic stirrer for 2 h, then this mixture was placed in a water bath (90 °C) to evaporate the solvent. The solvent evaporation method. A blend of crospovidone and sodium starch glycolate was prepared then mixed with several excipients to produce orally disintegrating tablets. Preparation of powder mixture was performed by mixing the component in table 1. Inclusion complex of atenolol-β-cyclodextrin which have been prepared then mixed with several excipients to produce orally disintegrating tablets. Preparation of powder mixture of compression was performed by mixing the component in table 1.

Preparation of powder mixture

Table 1: Formula of atenolol orally disintegrating tablet using co-processed crospovidone-sodium starch glycolate

<table>
<thead>
<tr>
<th>Contents</th>
<th>Co-processed Formula 1 (mg)</th>
<th>Co-processed Formula 2 (mg)</th>
<th>Physical mixture Formula 3 (mg)</th>
<th>Physical mixture Formula 4 (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atenolol-β-cyclodextrin</td>
<td>113.41</td>
<td>113.41</td>
<td>113.41</td>
<td>113.41</td>
</tr>
<tr>
<td>Co-processed crospovidone-sodium starch glycolate</td>
<td>30 (1:1)</td>
<td>30 (1:2)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Physical mixture crospovidone-sodium starch glycolate</td>
<td>-</td>
<td>-</td>
<td>30 (1:1)</td>
<td>30 (1:2)</td>
</tr>
<tr>
<td>Avicel PH 102®</td>
<td>94.87</td>
<td>94.87</td>
<td>94.87</td>
<td>94.87</td>
</tr>
<tr>
<td>Mannitol DC</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
<td>23.72</td>
</tr>
<tr>
<td>Aspartame</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>Mint flavor</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Magnesium stearate</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Talk</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Aerosil 200®</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Water absorption ratio

The weight of the tablet before keeping in the Petri dish was noted (Wb). Fully wetted tablet from the Petri dish was taken and reweighed (Wa). The water absorption ratio can be determined according to the following formula.

\[ R = \frac{Wb-Wa}{Wb} \times 100 \]

In vitro dispersion time

In vitro dispersion time was measured by dropping a tablet in a cylinder containing 6 ml of phosphate buffer pH 6.8 (simulated saliva fluid) with a temperature of 37±0.5 °C. The time required for complete dispersion was determined [17, 18].

Dissolution study

In vitro dissolution study was performed using USP Type II Apparatus (paddle type) at 50 rpm for 120 min. Acetate buffer pH 4.6 was used as a dissolution medium which was maintained at 37±0.5 °C. An aliquot (10 ml) was taken at specified time intervals (1, 2, 5, 15, 20, 45, and 60 min). An equal amount of fresh dissolution medium was replaced immediately following the withdrawal of the sample. The concentration of atenolol in the aliquot was determined using Ultra Performance Liquid Chromatography (UPLC). The data shown is the average of 6 determinations. A dissolution profile for each formula was plotted, and dissolution parameters such as %Q, %TQ, AUC, and dissolution efficiency was determined.
RESULTS AND DISCUSSION
In this study, four formulas have been prepared to produce orally disintegrating tablets of atenolol-β-cyclodextrin. Two formulas (formula 1 and formula 2) were prepared using two different ratios of co-processed crospovidone-sodium starch glycolate. Formula 3 and formula 4 were prepared as a control, using a physical mixture of crospovidone-sodium starch glycolate in the same ratio compared to the co-processed superdisintegrants.

The powder mixture of each formula was compressed using direct compression technique. The compressed tablets were evaluated for physical properties such as organoleptic, dimension, uniformity of weight, wetting time, water absorption ratio, and homogeneity of compressed tablets. The results of wetting time evaluation were shown in table 2. The wetting time is an essential parameter for orally disintegrating, and those have to be ideally less than 1 min [21]. The wetting times of formula 1 and formula 2 which used co-process superdisintegrants satisfied the criteria of wetting times. The results of statistical analysis using One Way ANOVA revealed that there was a significant difference (p<0.05) of wetting time among all formulas. The wetting time of atenolol orally disintegrating tablets which used the physical mixture of these superdisintegrants. Hence, there was no significant difference in wetting time between orally disintegrating tablets of atenolol which used co-processed crospovidone-sodium starch glycolate in 1:1 ratio and 1:2 ratios. One of the most desirable properties of the disintegrants is rapid swelling without gel formation since high viscosity on the surface of the tablet will prevent water penetration into the tablet matrix [5]. It was observed that co-processed superdisintegrants produce the inner structure of an orally disintegrating tablet more porous so that the wetting time became shorter.

Orally disintegrating tablets of atenolol which used co-process crospovidone-sodium starch glycolate exhibited shorter wetting time and needed less water to disintegrate. It was observed from the results of the water absorption ratio test. Water absorption ratio is an important criterion for understanding the capacity of disintegrants to swell in the presence of a little amount of water [21]. Orally disintegrating tablets of atenolol-β-cyclodextrin which used co-process crospovidone-sodium starch glycolate 1:1 showed the lowest water absorption ratio (p<0.05) compared to the other formulas. The difference in water absorption ratio among the four formulas in this study was due to the water uptake and the swelling behavior of superdisintegrants [22]. The difference of super-disintegrants preparation (co-processed and physical mixture) also influence the water absorption ratios of atenolol-β-cyclodextrin orally disintegrating tablets. Co-processed super-disintegrants reduce the water absorption ratio of orally disintegrating tablets, therefore the wetting time of the tablets became shorter. It can be concluded co-process superdisintegrants produce the higher ability of superdisintegrants to wick the water inside their structure and become more hydrated. This phenomenon can occur because co-process crospovidone-sodium starch glycolate combined the capillary characteristics of crospovidone and swelling effect of sodium starch glycolate in tablets disintegration mechanism. Co-processed superdisintegrants promote shorter wetting time of the tablets without high water absorption inside the structure of the tablets. The small amount of water or moisture which penetrates inside the structure of the tablets will produce enough pressure to disintegrate atenolol-beta-cyclodextrin orally disintegrating tablets. Based on this facts, co-processed superdisintegrants were promising to attempt the physical stability problems of orally disintegrating tablets which are formulated using a high amount of superdisintegrants. However, the increasing of sodium starch glycolate portion in co-processed crospovidone-sodium starch glycolate 1:2 showed a significant escalation in water absorption ratio. This was due to the characteristics of sodium starch glycolate which absorbed water until 200%-300% [5, 23].

In vitro dispersion time is a special parameter in which the time needed by the tablets to produce complete dispersion is measured [24]. In vitro dispersion time describe the behavior of orally disintegrating tablets when contact with a small amount of saliva in the mouth cavity [25]. The internal structure of the tablets, water absorption mechanism, and swelling characteristic of superdisintegrants are suggested to be the mechanisms of disintegration [26]. The results of in vitro dispersion time indicated that orally disintegrating tablets of atenolol-β-cyclodextrin which used co-process crospovidone-sodium starch glycolate dispersed rapidly in the mouth less than 60 seconds. Meanwhile, disintegrating tablets of atenolol-β-cyclodextrin which using a physical mixture of crospovidone-sodium starch glycolate dispersed in the mouth longer. The results of statistical analysis using One Way ANOVA revealed that there was a significant difference (p<0.05) between

Table 2: The results of physical and chemical evaluation of atenolol-β-cyclodextrin orally disintegrating tablets (formula 1, formula 2, formula 3, and formula 4)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Specification</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organoleptic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td>Round</td>
<td>Formula 1 Round</td>
</tr>
<tr>
<td>Colour</td>
<td>White</td>
<td>Formula 2 White</td>
</tr>
<tr>
<td>Odor</td>
<td>Mint</td>
<td>Formula 3 Mint</td>
</tr>
<tr>
<td>Taste</td>
<td>Mint dan sweet</td>
<td>Formula 4 Mint dan sweet</td>
</tr>
<tr>
<td>Tablet dimension (D/T)</td>
<td>≤ 3.00</td>
<td></td>
</tr>
<tr>
<td>In vitro dispersion (seconds)</td>
<td>&lt;60 seconds</td>
<td></td>
</tr>
<tr>
<td>Wetting time (second)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Water absorption ratio (%)</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>AUC Dissolution</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dissolution Efficiency</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*(D/T): The ratio of the diameter and the thickness of orally disintegrating tablets. *results were expressed in mean±SD, n=6, SD-Standard Deviation
orally disintegrating tablets of atenolol-β-cyclodextrin using co-process crospovidone-sodium starch glycolate and physical mixture of this superdisintegrants. Such a difference in disintegration time between both preparations of superdisintegrants indicates which there might be an improvement of capillary action on co-process superdisintegrants. This condition which might have led to improving water uptake [18]. It was also observed that formula 1 which using co-process crospovidone-sodium starch glycolate 1:1 took the shortest time to disperse in the small amount of buffer phosphate pH 6.8 (±6 ml). There was a correlation between wetting time and in vitro dispersion time. The faster water can penetrate the structure of the tablets; the faster the tablets will be dispersed in the medium [25]. It was revealed that formula 1 which using co-process crospovidone-sodium starch glycolate 1:1 produce better wetting time, water absorption ratio, and in vitro dispersion time compare to the other formulas.

Dissolution study of atenol orally disintegrating tablets was performed in pH 4.6 acetate buffer using USP Dissolution test apparatus with a paddle stirrer. Profile dissolutions of atenol orally disintegrating tablet formula 1, formula 2, formula 3, and formula 4 are shown in fig. 1.

![Dissolution profile of orally disintegrating tablets of atenolol-β-cyclodextrin formula 1, formula 2, formula 3, and formula 4](image)

The result showed that formula 1 which using co-process crospovidone-sodium starch glycolate 1:1 release the highest amount of atenolol in 60 min among all formulas. Statistical analysis of area under the dissolution curve (AUC) using one-way ANOVA represented that there was a significant difference (p<0.05) between formulas which using co-process and physical mixture crospovidone-sodium starch glycolate. The results also revealed that formula 1 had shown the highest dissolution efficiency and the most rapid drug dissolution among all formulas. The rapid drug dissolution may be due to the presence of co-process superdisintegrants, which swells due to the rapid uptake of water from medium resulting in the breakdown of the tablet into smaller particles with the increased surface area, and hence increase the release of the drug into the dissolution medium [27, 28].

From this present work it concludes that co-process crospovidone-sodium starch glycolate implied positive impact on wetting time, water absorption ratio, dispersion time, and dissolution efficiency of atenolol-β-cyclodextrin orally disintegrating tablets. The results of evaluation parameters suggested that co-processed crospovidone-sodium starch glycolate in the 1:1 ratio was the best composition to produce efficacious orally disintegrating tablets of atenolol-β-cyclodextrin as compared to the physical mixture.

CONCLUSION

Based on the results of this study, it can be concluded that co-process superdisintegrants crospovidone-sodium starch glycolate could lead to the formation of rapid disintegrating and higher dissolution efficiency of atenolol-β-cyclodextrin compared to the physical mixture. Among four formulas which have been analyzed in this study, formula 1 (co-process crospovidone-sodium starch glycolate 1:1) is the best formulation because this formula dispersed in the least time and released the highest percentage of atenolol in the same time. The results also revealed that the difference of superdisintegrants preparation (co-process and physical mixture) and the amount of crospovidone and sodium starch glycolate which has been used in the formulas (1:1 and 1:2) significantly affect the dependent variables such as wetting time, water absorption ratio, *in vitro* dispersion time, and dissolution.

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AUTHORS CONTRIBUTIONS

All the author have contributed equally

CONFLICT OF INTERESTS

Declared none

REFERENCES