The effect of recompression and concentration of polyvinylpyrrolidone (PVP) K-30 on the quality of paracetamol tablets

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ABSTRACT

Quality control during production is a critical process that ensures the quality of the tablets until they reach the consumer. In the pharmaceutical industry, reworking is possible, including tablet recompression. Nevertheless, the recompression process may have affected the potential of PVP K-30 as a binder to reunite the particles of tablet ingredients. However, the difference in PVP K-30 concentration might result in differences in granule and tablet characteristics. This study aims to determine whether there is an effect of recompression and the difference in PVP K-30 on the quality of paracetamol tablets. The effect of recompression and the difference in PVP K-30 was seen based on whether there is a significant difference in the physical properties of the mixture of tablet ingredients (mixture's flow rate and compressibility) and the tablets (compactibility, tablet hardness, friability, and disintegration time) from the formula with a concentration of 2% w/w and 4% w/w PVP K-30 after experiencing 2 times of recompression. Paracetamol tablets were made by the wet granulation method through the stages of granulation, lubrication, physical properties testing of the mixture, tablet compression, physical properties testing of tablets, crushing, and recompression. Data analysis was performed statistically using the Shapiro-Wilk normality test, followed by a two-way analysis of variance (ANOVA), or Kruskal-Wallis test, and post-hoc Mann-Whitney test. The results showed there was an effect of recompression and different concentrations of PVP K-30 on the potential of PVP K-30 as a binder, as seen from the significant differences in the physical properties of the mixture and tablets in each test group.

Keywords: recompression, polyvinylpyrrolidone (PVP) K-30, paracetamol tablets, wet granulation.

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INTRODUCTION

Tablet pharmaceutical dosage forms are a widely used and generally preferred pharmaceutical solid dosage form. Tablets are easy and convenient to use, more accurate in dosage, and more stable in storage and distribution (Al-Zoubi et al., 2021). In addition to active pharmaceutical ingredients, tablets also contain excipients such as filler, binder, lubricant, disintegration, and if required a sweetening agent, flavoring agent, and coloring agent (Iqubal et al., 2014). Paracetamol is a drug with antipyretic and anti-inflammatory indications (Sugiyono et al., 2017). This active pharmaceutical ingredient has poor flow and compressibility characteristics, it had a wide particle size distribution (PSD) of irregular particles, which caused poor flowability and a high difference between bulk and tapped densities (Šimek et al., 2017). One way to improve these characteristics of paracetamol, is to produce paracetamol tablets using the wet granulation method. The wet granulation method is carried out by granulating the tablet ingredients with a liquid binder (Hiremath et al., 2019). Particle size enlargement and a more uniform shape of particles caused by granulation improve tablet materials' flow and compressibility characteristics.

Binders ensure that tablets, powders, granules and others can be formed with the required mechanical strength. Polyvinylpyrrolidone (PVP) K-30 is one of the binders that is commonly used in tablet manufacturing. In the tablet formulation, PVP K-30 as a binder was added at a concentration of 0.5-5% w/w (Sheskey et al., 2017). As a binder, PVP K-30 can produce granules with better flow characteristics, as well as higher binding strength and lower friability (Hiremath et al., 2019).

The quality of the tablet material mixture affects the quality of the tablet produced (Janssen et al., 2023). Evaluation of the mixture includes flow rate, compressibility, and compactibility. Besides, the quality of tablets is generally evaluated by their organoleptic, weight uniformity, hardness, friability, disintegration, and dissolution time profiles. The binder, as one of the essential components of the tablet, may influence the quality of the tablet. The amount of binder added to a tablet formula influences the physical characteristics of the granules and tablets produced. The addition of a large amount of binder produces tablets with high hardness characteristics and slow disintegration and dissolution times. Otherwise, a small amount of binder produces tablets with high friability characteristics (Puspita et al., 2022).

In tablet manufacturing, tablet quality is monitored from the material in the process to the finished product. However, occasionally the pharmaceutical industry faces problems related to the quality of tablets that do not meet the specifications required. To overcome the problem, the pharmaceutical industry could take reworking action against the problematic batch (BPOM, 2018). These processes are taken to obtain pharmaceutical dosage forms that fulfill quality criteria. During tablet manufacturing, the reworking action that could be carried out is recompression.

Recompression is the repeated compression of tablets under the same conditions as the first compression (Rojas et al., 2015). Nevertheless, crushing and recompression might alter of the mixtures and tablets physical characteristics. Related research that was conducted by (Rojas et al., 2015) shows that recompression caused a decrease in particle size, reduced porosity, increased compactibility, and decreased flow rate of the tablet material mixture. Otherwise, (Gamlen et al., 2015) conducted similar research that showed repeated compression and precompression did not affect the tensile strength of Avicel PH 101 tablets, although there was a small effect on the friability and disintegration time of the tablets. Moreover, there is an effect that decreased the tensile strength and increased the disintegration time of dicalcium phosphate dihydrate (DCP) tablets but improved the tensile strength and friability of Starch 1500 tablets. This study aims to determine whether there is an effect of recompression on the quality of paracetamol tablets.

MATERIALS AND METHOD
Materials

The materials that are used are paracetamol pharmaceutical grades, polyvinylpyrrolidone (PVP) K-30 pharmaceutical grades, lactose pharmaceutical grades, croscarmellose sodium pharmaceutical grades, talc pharmaceutical grades, magnesium stearate pharmaceutical grades, and aquadest.

Instruments

The instruments that are used are analytical balances Pioneer PA213 (OHAUS Stuccler, Putian, China), all-purpose machine GmBH AR 401(Erweka, Langen, Germany), sieve (cust, Indotest Multi Lab), flowability tester GmBH (Erweka, Langen, Germany), tap density volumizer HY-100B (Wincom Company Ltd., Changsha, China), drying cabinet, single punch tablet press machine (Korsch Maschinefabrik Berlin), vacuum (Chefinox Boombastic), friability tester CS-2 (Lorderan, Shanghai, China), hardness tester (Pharma Test PTB 302), disintegration tester Develop BJ-2 (Laboao International, Zhengzhou, China), Spectrophotometer UV-Vis (Shimadzu), mortar and stamper.

Methods

Preparation of PVP K-30 solution

This study used two levels of PVP K-30 concentration which are 2% w/w as formula 1 and 4% w/w as formula 2. PVP K-30 solution was prepared by dissolving PVP K-30 powder in aquadest solvent at concentration of 10% w/v for formula 1 and 20% w/v for formula 2.

Granulation method

Paracetamol, lactose, and ⅓ amount of croscarmellose sodium (Table 1) were weighing and mixed in a cube mixer with the mixer running for 15 minutes. The mixture was granulated by adding PVP K-30 solution little by little, up to 90 mL. The wet mass was milled to form granules through a sieve manually.

The wet granules were dried in the drying cabinet at a temperature of 50°C. The moisture content of granules was checked every 24 hours, and the moisture content was calculated by the following Equation 1.

$$\% \text{ Moisture content} = 100 \times \left(\frac{weight\ of\ wet\ granules\ -\ weight\ of\ dry\ granules}{weight\ of\ dry\ granules} \right) \quad \ldots\ldots\ldots\ldots(1)$$

The required moisture content of dried granules is not more than 5% (Crouter&Briens, 2013). Afterwards, the dried granules were sieved with 12/50 number mesh of sieve.

Lubrication method

Granules, ⅔ amount of croscarmellose sodium, and talc were mixed by mixer for 5 minutes. After the first mixing, magnesium stearate was added to the mixture, and the mixer was running for 5 minutes.

Mixture characteristic evaluation

Flowrate test

A total of 100 g of the mixture was loaded into the hopper of the flowability tester and the "START" button was pressed. The flow rate of the mixture tested was shown on the instrument screen. The requirement for a free to flow rate is > 10 g/s (Setyono & Purnawiranita, 2021). This measurement was taken 3 times.

Compressibility test

A total of 40 g of the mixture was loaded into the 100mL graduated cylinder without any tapping and then tapping 500 times using a tap volumeter. The closest scale of the graduated cylinder where the top of the mixture stuck before tapping was noted as starting volume (V_0) while after tapping it was noted as final volume (V_f). The compressibility of the mixture was determined by calculating the compressibility index using the following Equation 2.

$$compressibility\ index = 100\ x\ (\frac{V_0 - V_f}{V_0}) \quad ....(2)$$

If the mixture has excellent compressibility, it is indicated by a compressibility index <10%. This measurement was taken 3 times.

Table 1. The formula of paracetamol tablet

Ingredients	Function	Composition (mg)	
		Formula 1	Formula 2
Paracetamol	API	300	300
Lactose	Filler	238	226
PVP K-30	Binder	12	24
Aquadest	Binder solvent	90	90
Croscarmellose sodium	Disintegrant	20	20
Talc	Glidant	27	27
Magnesium Stearate	Lubricant	3	3

Notes:
Formula 1: formula with the concentration of 2% w/w PVP K-30
Formula 2: formula with the concentration of 4% w/w PVP K-30

Compactibility test

A portion of the mixture was compressed into tablets with various compression pressures by downscaling the upper punch scale from 1 mm, 2 mm, 3 mm, 4 mm, 5 mm, 6 mm, 7 mm, 8 mm, and 9 mm. Compactibility was measured according to the hardness of the tablet that was able to be compressed at each pressure applied, this measurement was taken three times.

Tablet compression

The mixture was compressed into tablets using a single-punch tablet press machine. The compression pressure was set based on the results of the previous orientation to produce tablets with a weight of 600 mg and a hardness in the range of 4-8 kg which is the upper punch with downscaling at 11 mm and the lower punch at 13 mm. The mixture was compressed with the same compression pressure for each formula.

Tablet characteristic evaluation
Organoleptic test

Tablets from each formula and each compression were tested organoleptically through sensory testing including tablet shape, color, and odor.

Weight uniformity test

One tablet taken randomly from each formula at each compression was determined for its assay using a UV spectrophotometer. The A value is calculated as the percentage of the measured amount of active ingredient content over the amount indicated in the etiquette. A total of 10 random tablets from each formula at each compression were weighted (w_i) and the average weight was calculated (w bar). The estimated content (X_i) of each tested tablet unit was calculated by the following Equation 3.

$$X_i = w_i \times (\frac{A}{\overline{W}}) \quad ……………………………………………(3)$$

The weight variation was determined by calculating the acceptance value (NP) by the following Equation 4.

$$NP = \left| M - \overline{X} \right| + ks$$ ………………………………………… (4)

Where M is the reference value, X is the average of the estimated contents of each unit of tablet tested, k is the acceptability constant (if n = 10, then k = 2.4; if n = 30, then k = 2.0), and s is the standard deviation. Weight variation is fulfilled if the acceptance value of the first 10 tablet units is not more than or equal to L1%. If the acceptance value is greater than L1%, then the weight variation test is applied to an additional 20 units of tablets (Direktorat Jenderal Kefarmasian dan Alat Kesehatan, 2020).

Hardness test

A total of five tablets taken randomly from each formula at each compression and recompression were placed on the pressing pad, and then the "START" button was pressed to operate the hardness tester. The hardness result (kg) of the tested tablets will be shown on the screen of the hardness tester instrument. Tablet hardness measurement was done three times with the requirement of good tablet hardness between 4-8 kg (Rori et al., 2016).

Friability test

A total of 20 tablets randomly chosen from each formula in each compression and recompression were weighed after removing any loose dust from those tablets first. The weight result was determined as the initial weight. The tablets were put into the friability tester and operated with 100 rotations. The tablets were removed from the instrument and dedusted again. Twenty tablets were weighed, and the weight result was determined as the final weight. Tablet friability was evaluated based on its percentage friability which was measured by the following Equation 5.

$$\% \; friability = \frac{initial \; weight - final \; weight}{initial \; weight} \times 100\%$$ ...………….………(5)

The requirement for good friability is % friability of no more than 1% (Rori et al., 2016). The measurement was taken 3 times.

Disintegration test

One tablet taken randomly from each formula at each compression and recompression was placed in each of the six tubes in the basket. The basket was dipped in a medium of water at a temperature of $37\pm2°C$, then the disintegration tester was turned on. The requirement for a good tablet disintegration time is that the tablet be destroyed in no more than 15 minutes (Rori et al., 2016).

Crushing

All tablets remaining after the physical characteristics testing were crushed using a mortar and stamper with a constant crushing force. The mixture was sieved using a sieve with a mesh number 12/50. Crushing was repeated twice for each formula.

Tablet recompression

The sieved mixture from the crushing step was recompressed using a single punch tablet compression machine with the same compression method as the first tablet compression. Recompression was done twice for each formula.

Data Analysis

The data obtained were the results of the physical characteristics testing of the mixture, including flow rate, compressibility, and compactibility of the mixture; and the physical characteristics of the tablets, including hardness, friability, and disintegration time of the tablets. The data distribution was tested with the Shapiro-Wilk normality test. If the data is normally distributed, statistical analysis of the data is continued using the two-way analysis of variance (ANOVA) test, if it is not normally distributed, it is continued using the Kruskal-Wallis test with a confidence level of 95% and a p-value <0.05. Kruskal-Wallis's analysis then continued with the post-hoc Mann-Whitney test to find out the differences between the data groups. Significant differences between the data groups shown statistically identify the effect of re-compression and concentration of PVP K-30 on the physical characteristics of the mixture and the tablets produced.

RESULT AND DISCUSSION

In this study, binder concentrations of 2% and 4% were used, taking into consideration that the concentration range of PVP K30 as a binder was 0.5-5%, so concentrations of 2% and 4% could be used to see the effect of different PVP concentrations on the physical properties of the paracetamol tablet. The granules were tested for moisture content using the gravimetric method, and the moisture content of the formula 1 granules was 2.92% and the formula 2 granules was 3.77%. The mixture is a combination of granules and powders of disintegrant, and lubricant material mixed at the lubrication step. Testing of the physical characteristics of the mixture was carried out on the initial mixture before compression (mixture I), the mixture of crushed tablets from the first compression (mixture II), and the mixture of crushed tablets from the first re-compression (mixture III). Before testing, the whole mixture was sieved first with a 12/50 mesh sieve. Testing of the physical properties of tablets was performed on the first compressed tablet (tablet I), the first re-compressed tablet (tablet II), and the second re-compressed tablet (tablet III). Recompression of the tablet was conducted twice because of the lack of a tablet machine, that couldn't compress for the third recompression.

Physical characteristics testing of mixtures

The physical characteristics of the mixture are observed based on the flowability and compactibility of the mixture. Good mixture flow is necessary to ensure uniform filling into the die hole, which directly determines the weight variation of the tablets. The flow characteristics of the mixture was performed by measuring the flow rate and compressibility of the mixture as shown in Table 2.

Flow rate through an orifice is generally measured as the mass of material per unit time flowing from any of several types of containers (cylinders, funnels, hoppers). It is thought to be a more direct measure of flow than measurements such as angle of repose (Amidon et al, 2017). Shape, size, and size distribution factors greatly influence the flow characteristics of the mixture. A spherical particle shape will improve the flow of the mixture (Chen et al., 2019). However, in this study, the particle shape of the mixture was not examined in detail, so it could not be ascertained how it looked before and after crushing.

Table 2. The flow characteristic of the powder mixture in each formula

The parameter of flow characteristics	Formula 1			Formula 2		
	Mixture I	Mixture II	Mixture III	Mixture I	Mixture II	Mixture III
Flow rate (g/s) $\overline{X} \pm SD$	42.9 ± 2.2	32.7 ± 1.6	29.2 ± 1.8	47.0 ± 2.6	39.0 ± 0.9	31.7 ± 2.4
Carr index (%) $\overline{X} \pm SD$	3.3 ± 0.04	8.4 ± 1.01	7.4 ± 0.1	6.0 ± 0.7	7.8 ± 1.1	7.1 ± 0.1

Notes:

$\overline{X}$: average of 3 measurements

SD   : standard deviation
Formula 1 : formula with the concentration of 2% w/w PVP K-30
Formula 2 : formula with the concentration of 4% w/w PVP K-30
Mixture I   : initial mixture
Mixture II : the mixture of crushed tablets from the first compression
Mixture III: the mixture of crushed tablets from the first re-compression

The results showed that the flow rate and compressibility index of the mixture of both formulas before and after compression-recompression were > 10 grams/second and < 10%, respectively, so the mixture was classified as having good flow characteristics. The results of Kruskal-Wallis's analysis showed p-values of 0.009 and 0.014 respectively, for the test groups of flow rate and compressibility of the mixture. Mann-Whitney follow-up test showed that there was an effect of re-compression and different concentrations of PVP K-30 on the flow rate and compressibility of the mixture. In this research, the recompression process was still carried out, even though the powder mixture profile and physical properties of the tablets had met the requirements, considering that this research aimed to see the effect of recompression on the quality of the paracetamol tablet. One of the limitations of this research is that the crushing process was carried out manually, not using a special machine. This can affect the particle size distribution of the granules produced and the flow characteristics of the granules after recompression.

The mixture of formula 2 with a higher concentration of PVP K-30 has a faster flow rate than the mixture of formula 1. The higher the concentration of binders, the greater the cohesiveness of the powder to form granules and the larger the granule's size (Köster & Kleinebudde, 2024). Research conducted by (Puspita et al., 2022) showed similar results whereby a large granule size reduces friction between particles and the hopper wall. In addition, the gravity increases as the granule size increases, making the mixture's flow easier (Schlick-Hasper et al., 2022).

In contrast, crushing after compression and re-compression caused a decrease in flow rate and an increase in the compressibility index of the mixture, although it was still within the required range. The manual crushing technique with an attempted constant crushing force could not guarantee the same force at each crushing. Overpowering crushing produces small particles or fines, while underpowering produces large particles. Although the size distribution is maintained by sieving, there is an increase in fines due to crushing.

Small particle size creates a larger specific surface area and increases interaction between the mixture particles and the hopper surface, which prevents the flow of the mixture (Syukri, 2018). Small particles tend to fill up the large particle pores, increasing the volume reduction and thus increasing the compressibility index of the mixture (Ulusoy, 2023). The initial mixture before the first compression has the highest flow rate and the smallest compressibility index value because its particles have better uniform shape, size, and size distribution. The lesser inter-particle interaction causes the mixture to flow and settle more easily (Khaidir et al., 2015).

Compactibility is the ability of a material to form tablets of sufficient tensile strength under the effect of densification and is strongly correlated with the strength of interparticulate bonds in the compact (bonding strength) (Apeji et al, 2019). The parameter of the mixture's compactibility is the hardness of the tablet compressed with various compression pressures (Huda & Sari, 2021). The mixture that can form hard tablets under applied pressure without showing a tendency to caping possesses good compactibility. Table 3 shows the hardness results of the compactibility test with a 10 mm lower punch.

Fines increased due to crushing will fill the pores between particles thus the porosity decreases and the hardness and compactibility of the mixture increase (Solikhati et al., 2022. The increased compactibility of mixtures II and III is indicated by an increase in tablet hardness on the same punch scale as mixture I. Meanwhile, the mixture that became tighter as recompression led to the machine's

inability to compress the tablets with higher pressure. At the upper punch downscale of 8 mm (except mixture I of formula 1) and downscale of 9 mm, all mixtures could not be compressed due to the machine jamming and releasing a loud noise. Recompression caused increased compactibility of the mixtures, resulting in increased hardness of the tablets at each compression.

Table 3. The compactibility of the powder mixture in each formula

Downscaling upper punch (mm)	Tablet's hardness (kg)					
	Formula 1			Formula 2		
	Mixture I	Mixture II	Mixture III	Mixture I	Mixture II	Mixture III
1	*	*	*	*	*	*
2	*	*	*	*	*	*
3	*	*	*	*	*	*
4	*	*	*	*	*	*
5 ± SD	0.05±0.01	0.46±0.05	1.06±0.12	0.07±0.01	0.39±0.04	1.68±0.19
6 ± SD	0.16±0.05	3.46±0.24	4.59±0.31	0.77±0.23	4.58±0.28	5.56±0.44
7 ± SD	2.28±0.50	5.66±0.06	6.97±0.25	3.8±0.08	7.47±0.42	9.29±0.23
8 ± SD	4.66±0.28	#	#	#	#	#
9	#	#	#	#	#	#

Notes:

The result is an average of 3 measurement

*   : the mixture could not yet compress

\#   : the machine cannot compress the mixture

Formula 1   : formula with the concentration of 2% w/w PVP K-30

Formula 2   : formula with the concentration of 4% w/w PVP K-30

Mixture I   : initial mixture

Mixture II   : the mixture of crushed tablets from the first compression

Mixture III   : the mixture of crushed tablets from the first re-compression

The mixture of formula 2 with 4% w/w PVP K-30 produced tablets with higher hardness than the mixture of formula 1 with 2% w/w PVP K-30 at the same punch scale. This indicates that the concentration of binder could affect the tablet hardness (Mahours et al, 2017). Binders play a role in forming compact tablets through compression.

Kruskal-Wallis statistical analysis was applied to the 5 mm and 6 mm compactibility test groups, with p-value of 0.006 for both test groups. The follow-up Mann-Whitney test showed that there was an effect of recompression action and different concentrations of PVP K-30 on the compactibility of the mixture. Meanwhile, the 7 mm compactibility test group was statistically analysed with the two-way Anova test and obtained a p-value <0.001 for the formula and compression variables, and p value of 0.069 for the interaction between formula and compression. In compactibility analysis, a different statistical method is used because the data is not normally distributed, so two-way anova analysis cannot be used, and must use Kruskal-Wallis's analysis.

Physical characteristics testing of tablets

Tablets from both formulas as a result of each compression had an organoleptic round shape, white in colour (Figure 1 and 2) and were odourless. However, caping occurred in the tablets from the first and second re-compression of formula 1 (Figure 1). One of the causes of caping is the lack of binding agent concentration in tablets (Mashabai et al., 2022). Besides, increased fines can lead to caping because there is air entangled between the fines in the mixture which expands when the compression pressure is released. The presence of capping in the recompression process can be caused by

differences in particle size distribution that are too large, resulting in a void volume containing air. As a result, when it is compressed, the air trapped in the powder will try to escape, causing tablet to cap.

Figure 1. The organoleptic of paracetamol tablet resulted from Formula 1 (A) first compression tablet (B) first recompression tablet (C) second recompressed tablet

Figure 2. The organoleptic of paracetamol tablet resulted from Formula 2 (A) first compression tablet (B) first recompression tablet (C) second recompressed tablet

Tablet compression pressure influences the physical properties of the tablets produced. In this study, the tablet compression pressure was kept the same for each compression and recompression so that the physical properties of the tablets produced could be compared. However, as the study goes on, the reality is that crushing, and recompression cause the physical properties of the mixture to change. These changes caused the machine to be unable to recompress the tablets at the initial pressure. Nonetheless, the compression pressure was kept the same for each compression as much as possible, considering the ability of the tablet compression machine to lower the pressure when required. Table 4 shows the physical characteristics of the tablet.

Weight variation for tablets with active ingredient content > 25% of tablet weight is taken to ensure uniformity of active ingredient content in tablets. Weight variation is strongly influenced by the flow characteristics of the mixture, the more uniform the amount of mixture that enters the die hole resulting the more uniform the tablet weight (Puspita et al., 2022). The results in Table IV show that the tablets of both formulas in each compression and recompression have met the requirements of the weight variation acceptance criteria, which is NP of the first 10 tablet units is maximum 15. All mixtures still qualify for good flow characteristics so weight variation can still be achieved.

Tablet hardness describes the overall resistance of the tablet to mechanical stresses such as cracking and breaking of the tablet. Tablet hardness increases with the amount of recompression applied. The greater the number of compressions, the denser the particles of the crushed tablet mixture. In the second compression, the tablet was compressed twice and crushed twice so that the particles of the mixture were more compact, and the tablets produced had the highest hardness. Only

tablet III did not meet the hardness requirement of 4-8 kg. Meanwhile, the higher the concentration of binder, the harder the tablet produced (Osman et al., 2019). Tablets of formula 2 have a higher hardness than tablets of formula 1.

Table 4. Physical characteristics testing of paracetamol tablets

Physical characteristics	Tablet					
	Formula 1			Formula 2		
	I	II	III	I	II	III
Weight variation (NP)	2.9	2.33	4.95	8.05	3.03	3.38
Hardness (kg) $\overline{X} \pm SD$	4.4$\pm$0.04	5.4$\pm$0.09	6.6$\pm$0.07	4.5$\pm$0.03	7.01$\pm$0.11	13.3$\pm$0.09
Friability (%) $\overline{X} \pm SD$	0.58$\pm$0.16	6.32$\pm$0.15	5.72$\pm$0.64	0.48$\pm$0.02	2.97$\pm$0.28	1.09$\pm$0.11
Disintegration time (minutes) $\overline{X} \pm SD$	0.75$\pm$0.16	1$\pm$0,03	1.28$\pm$0.03	1.40$\pm$0.02	2.37$\pm$0.06	2.54$\pm$0.03

Notes :

NP	: acceptance value
$\overline{X}$	: average of 3 measurements
SD	: standard deviation
Formula 1	: formula with the concentration of 2% w/w PVP K-30
Formula 2	: formula with the concentration of 4% w/w PVP K-30
I	: tablet from first compression
II	: tablet form first recompression
III	: tablet from second recompression

Tablet friability describes the resistance of the tablet surface to friction or scraping (Osei-Yeboah & Sun, 2015). The results showed that only the first compressed tablets from both formulas met the requirements of good tablet friability of < 1%. The increase in friability in tablets from re-compression may be due to crushing after compression, which has created a new surface on the mixture particles that may not contain a binder. It decreases the binding force between particles so that the resistance on the tablet surface decreases and the friability increases (Suhery et al., 2016). However, there was a decrease in the % friability of the tablets from the second re-compression compared to the first recompressed tablets. This was probably due to an increase in hardness, where the harder the tablet, the lower the friability (Khaidir et al., 2015). In general, an increase in tablet hardness is accompanied by a decrease in tablet friability. In this study, the increase in tablet hardness was accompanied by an increase in friability as well. This can be caused by differences in particle distribution that are too large, so that the presence of fine-sized particles will increase the brittleness of the tablet when compressed.

In addition, the fines that caused the capping of the re-compressed tablets from Formula 1 resulted in the highest % friability of the tablets. Tablets of Formula 2 did not have capping which resulted in a smaller % friability because the binder reduced the friability of the tablets produced. Polyvinylpyrrolidone (PVP) K-30 as a binder produces fewer fines (Putra et al., 2019).

Tablet disintegration time describes the time required for a tablet to disintegrate after contact with the gastrointestinal fluid (Khaidir et al., 2015). All tablets had a good disintegration time of no more than 15 minutes. The re-compression action and higher concentration of PVP K-30 led to an increase in tablet disintegration time. The porosity of the tablets that decreased along with the number of recompressions caused the tablets to absorb water slower, and the longer it took for the tablets to

disintegrate (Rahayu & Anisah, 2021). Meanwhile, higher concentrations of binders produce stronger granule bonds and harder tablets that prevent the tablets from disintegrating easily.

Two-way ANOVA statistical analysis was applied to the tablet hardness, friability, and disintegration time test data groups. All test data groups produced p values <0.001 in the variable's formula, number of compressions, and interaction between formula and number of compressions. These results mean that there is an effect of different concentrations of PVP K-30 and re-compression, and there is a relationship between different concentrations of PVP K-30 and re-compression on the physical properties of tablet hardness, friability, and disintegration time.

CONCLUSION

It can be concluded that there is a significant effect of recompression and different concentrations of PVP K-30 on the physical properties of the mixture (flow rate, compressibility, and compactibility of the mixture) and the physical properties of paracetamol tablets (tablet hardness, friability, and disintegration time).

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