JURNAL FARMASI SAINS DAN KOMUNITAS
Journal of Pharmaceutical Sciences & Community

p-ISSN 1693-5683; e-ISSN 2527-7146

Vol. 22, No. 2, November 2025, pp. 229-238 Research Article

Design, Formulation, and Evaluation of Vitamin C Tablets Using Co-Processed Excipient Combination of Jackfruit Seed Starch and Avicel® PH 101

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https://doi.org/10.24071/jpsc.008319

J. Pharm. Sci. Community, 2025, 22(2), 229-238

Article Info

Received: 2024-03-04
Revised: 2024-07-06
Accepted: 2024-08-30

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Keywords:
Co-processed excipient; Direct compression; Filler agent; Tablet; Tabletting method

ABSTRACT

Tablet is a popular pharmaceutical dosage form among the public. One method of making tablets is direct compression. This method must consider the flow properties and compressibility of the excipients. But many excipients do not meet these criteria, leading to the alternative use of co-processed excipients of jackfruit seed starch and avicel® PH 101. This research aims to determine the physical characteristics of direct compression vitamin C tablets using co-processed excipient of PBN-A (Jackfruit Seed Starch and Avicel® PH 101) with varying ratios of 1:3, 3:1, and 1:1. The research methods include powder preparation, powder evaluation, tablet compression, and physical evaluation of tablet. Descriptive and statistical data analysis using one-way ANOVA. The research results show that tablets exhibit favorable physical characteristics in F1, but F2 and F3 show suboptimal hardness and friability values. The statistical analysis results indicate a significant difference with a p-value of (0.000) and post-hoc tests explain that these significant differences are particularly noticeable between F1 and F2, K1, and K2. This study concludes that vitamin C tablets using co-processed excipients of PBN-A with ratios of 1:3, 3:1, and 1:1 exhibit good physical characteristics in all evaluations, except for the hardness and friability of F2 (3:1) and the hardness of F3 (1:1).

INTRODUCTION

Tablets are a pharmaceutical dosage form that is most used in society. Tablets contain one or more active ingredients, with or without excipients (Mustarichie and Priambodo, 2018). The tablet dosage form has advantages such as modifiable appearance to make it more attractive, good uniformity, accurate dosing, easy administration, chemical and physical stability, and relatively practical packaging and storage (Murtini and Elisa, 2018). Several methods in tablet manufacturing include direct compression, dry granulation, and wet granulation. The easiest method to make tablets is direct compression or molding. The direct compression method is most considered because it involves only mixing the active ingredients with appropriate excipients and then compressing them without a prior granulation process, thus reducing production time and costs (Murtini and Elisa, 2018). However, in selecting the direct compression technique, attention must be paid to the nature of the active ingredients and excipients to be used, especially the flow properties and compressibility of the materials (Margret and Madhavi, 2020).

Vitamin C is an active ingredient readily soluble in water, unstable in humid conditions, and readily oxidized by light and heat (Sheskey *et al.*, 2020). Vitamin C can be easily oxidized because the compound contains a highly reactive hydroxyl functional group. In the presence of an oxidizing agent, the hydroxyl group is oxidized to a carbonyl group. The oxidation process can be hindered when vitamin C is very acidic or at low temperatures (Hapsari *et al.*, 2023).

Furthermore, vitamin C has medium flowability and good compressibility (Mullaicharam and Al-qartoobin, 2013). Therefore, vitamin C is made by direct compression tablet manufacturing method and attention must be paid to the selection of filler ingredients. Some commonly used filler excipients in the market include lactose, Avicel® PH 101, mannitol, and starch. Both lactose, starch, and mannitol have poor flow characteristics, so they cannot be directly added as excipients for direct compression. Meanwhile, Avicel® PH 101 has good flow and compressibility characteristics, but it is relatively expensive and less efficient when used at high concentrations, since it can increase production costs (Cabral *et al*., 2021).

Therefore, alternative excipients are sought for making direct compression tablets, one of which is co-processed excipients. Co-processed excipients are combinations of two or more ingredients merged using techniques that can enhance flowability, compressibility, and disintegration potential with the combination (Bhatia *et al*., 2022). One co-processed excipient that can be considered is the combination of Jackfruit Seed Starch (PBN) and Avicel® PH 101 (PBN-A). Starch is a common excipient used in tablet production as a filler, disintegrant, and binder. Various types of starch, including PBN, can be used in tablet formulations as filler materials (Sathianarayanan, 2023). Avicel® PH 101 is one microcrystalline cellulose (MCC) variant commonly used in the pharmaceutical industry as a filler, binder, disintegrant, and tablet lubricant (Rowe *et al*., 2009). Avicel® PH 101 has good flow and compressibility characteristics as a tablet binder and filler (Zhao *et al*., 2022). The combination of PBN-A as a co-processed excipient has been rarely studied or even yet to be studied. Until now, research on PBN as a tablet excipient has been in the form of pregelatinized modification and used as a gelatin and disintegrator (Rosa *et al*., 2020; Aliyatunnaim *et al*., 2022). This study uses natural PBN as a combination material with Avicel® PH 101 as a filler-binder for tablets. A study by Soedirman *et al*. (2009) mentioned that combining Avicel with starch is suitable for effective and rapid disintegration in tablet formulations.

Based on the description above, it is known that the co-processed excipients PBN and Avicel® PH 101 have the potential to be innovations as excipients in direct compression tablets of vitamin C. Therefore, this research was conducted to determine the physical characteristics of direct compression vitamin C tablets using the co-processed excipients Jackfruit Seed Starch (PBN) (*Artocarpus heterophyllus* Lam.) and Avicel® PH 101.

METHODS

The tools used during the research include a single punch tablet press machine (MKS-TBL55), hardness tester (Erweka), disintegration tester (Erweka), friability tester (TFT-2-D), moisture analyzer (Mettler Toledo), flowability tester, tap density tester, analytical balance (Shimadzu), sieves, stopwatch, mortar, stamper, and glassware equipment (Iwaki and Pyrex).

The materials used during the research include vitamin C (Bratachem), co-processed excipient PBN-A, magnesium stearate (Bratachem), and primogel (Gujarat Overseas INC).

Preparation of Co-Process Excipient PBN-A

Each Jackfruit Seed Starch (PBN) and Avicel® PH 101 in a ratio of 1:3, 3:1, and 1:1 was processed by grinding them in a mortar and then homogenizing them. The mixture was then dispersed in distilled water which was then dried using a spray drying machine set at an inlet temperature of 150 and an outlet temperature of 100. The suspension was sucked into the device via a hose assisted by a pump and converted into small, fine drops through a 2.4 mm nozzle tip. The suspension was aspirated at a speed of 20 mL/minute. The mixture formed was dried in a desiccator for at least 1 day. The co-process excipient results were sieved using a 12 mesh sieve (Sa'adah and Fudholi, 2011).

Tablet Powder Preparation

Vitamin C, co-processed excipient PBN-A, magnesium stearate, and primogel were each weighed and sieved using a mesh size of 20. Then, all ingredients were mixed until homogenous. The tablet formula design can be seen in Table 1.

Evaluation of Tablet Powder

Moisture Content Test

Approximately 0.5 grams of powder was placed into the moisture analyzer, the device is run, and the moisture content is recorded. The testing was in triplicate (Halim *et al*., 2020; Ishikawa *et al*., 2021).

Compressibility Test

A 100 mL measuring glass was weighed on an analytical balance, and then the powder added to the measuring glass until it reached a volume of 100 mL. The measuring glass containing the

Table 1. Formula design of direct compression vitamin C tablet

Ingredients	Function	F1	F2	F3	K1	K2
Vitamin C	Active ingredient	50 mg	50 mg	50 mg	50 mg	50 mg
Mg stearate	Lubricant	1%	1%	1%	1%	1%
Primogel	Disintegrant	2%	2%	2%	2%	2%
Co-processed excipient PBN-A	Filler-binder	72%	72%	72%	-	-
Jackfruit seed starch (PBN)	Filler	-	-	-	-	72%
Avicel® PH 101	Filler	-	-	-	72%	-
Tablet weight		200 mg	200 mg	200 mg	200 mg	200 mg

Explanation:
F1: Formula 1 with PBN-A ratio (1:3)
F2: Formula 2 with PBN-A ratio (3:1)
F3: Formula 3 with PBN-A ratio (1:1)
K1: Control 1 using only jackfruit seed starch
K2: Control 2 using only Avicel® PH 101.

powder was re-weighed to determine the weight of the powder before tapping. Tapping was performed on the powder at 100 taps per minute using a tap density tester until the powder volume was constant, and then the final volume was recorded. The bulk density of the powder was calculated before and after compression, and the compressibility percentage (Carr's index) was also then calculated (Ishikawa *et al*., 2021; Phatan *et al*., 2024). Below are the equations for compressibility percentage:

$$\rho \text{ bulk} = \frac{\text{Powder weight}}{\text{Volume before tapping}}$$

$$\rho \text{ tap} = \frac{\text{Powder weight}}{\text{Volume after tapping}}$$

$$\%\text{Compressibility} = \frac{\rho \text{ tap} - \rho \text{ bulk}}{\rho \text{ tap}} \; x \; 100\%$$

Explanation:
ρ bulk : Bulk density of powder before tapping
ρ tap : Bulk density of powder after tapping
(Rahmayanti, 2021; Khasanah *et al*., 2023; Phatan *et al*., 2024)

Angle of Repose Test

A sample of 50 grams was placed in a funnel-shaped flow tester, and then the sample allowed to flow. The static angle of repose was determined by measuring the height and diameter of the cone (Ponnaganti and Anke, 2022; Phatan *et al*., 2024). The formula for calculating the angle of repose is as follows:

$$\alpha = [\tan]^{-1} \frac{h}{r}$$

Explanation:
α = angle of repose (°)
h = height of the cone (cm)
r = radius of the cone (cm)
(Nnamani and Eraga, 2022; Phatan *et al*., 2024)

Flow Rate Test

The sample was weighed to 50 grams and then placed into the funnel of the flow tester with the bottom hole closed. The cover was then opened to allow the sample to flow. The flow time was measured using a stopwatch from the moment the bottom hole was opened until the entire sample flowed out. The flow rate was expressed in grams per second (Halim *et al*., 2020; Ishikawa *et al*., 2021).

Direct Compression Tablet Manufacturing

A quantity of co-processed excipients PBN-A, magnesium stearate, primogel, and vitamin C were each sieved with a 20-mesh sieve. Then the three ingredients according to tablet 1 were mixed until homogeneous for around 5-10 minutes. They were then compressed for 3 seconds with a pressure of 1 ton using a single-punch tablet press machine (Nazib, 2006).

Physical Evaluation of Direct Compression Tablet

Uniformity of Weight Test

Twenty tablets were weighed using an analytical balance to perform the uniformity of weight test. The average weight of the tablets and the percentage deviation of each tablet was then determined. The provisions for uniformity of weight for tablets (uncoated and film coated) with a weight of 80-250 mg was a maximum percentage deviation for each tablet of 7.5% from the average tablet (EEC, 2020).

Uniformity of Size Test

Twenty tablets were used for the uniformity of size test. The automatic hardness tester is the instrument used to measure the

thickness and diameter of each tablet. This instrument will directly display the results of the tablet's diameter and thickness (Tafere *et al.,* 2021). The criteria for this test are that the diameter of each tablet must not be more than 3 times or must not be less than 4/3 of the thickness of the tablet (Kemenkes RI, 2020).

Tablet Hardness Test

The hardness tester is used to test the hardness of the tablets. Ten tablets were used, and the sample tablets were placed between the plates of the hardness tester. The instrument will display data on the hardness of the tablets (Ponnaganti and Anke, 2022; Phatan *et al.,* 2024).

Tablet Friability Test

The friability tester is used to test the friability of tablets. Ten tablets were cleaned, weighed, and placed into the testing apparatus. The apparatus was operated at a speed of 25 rpm for 4 minutes. Then, the tablets were removed, cleaned, and weighed again. The percentage friability of the tablets was then calculated (Nnamani and Eraga, 2022; Ponnaganti and Anke, 2022; Phatan *et al*., 2024).

$$\%\text{Friability} = \frac{W0 - W1}{W0} \times 100\%$$

Explanation:
W0 = initial tablet weight
W1 = final tablet weight
(Ponnaganti and Anke, 2022; Phatan *et al*.,2024)

Tablet Disintegration Time Test

Each tablet was placed into six tubes on the disintegration tester. Then, discs were inserted into each tube and the device was run for 15 minutes at a temperature of 37°C ±2°C. If one or two tablets did not disintegrate during these 15 minutes, then the test was repeated using another 12 tablets, and the result should not be less than 16 out of 18 tablets tested that must have disintegrated completely (Ministry of Health, Republic of Indonesia, 2020).

Data Analysis

The data were analyzed descriptively and statistically. Descriptive analysis involves describing and comparing the results obtained in powder evaluation and physical tablet characteristics with the requirements specified in the literature. Meanwhile, statistical data analysis for the results of tablet physical characteristic evaluations used a one-way Analysis of Variance (ANOVA) test with a confidence level of 95%.

RESULTS AND DISCUSSION

Powder Preparation Results

The tablet preparation in this study utilizes the direct compression method. Thus, the preparation involves only weighing, sieving, and mixing all ingredients until homogeneous. Sieving each ingredient aims to ensure that the powder particles are of uniform size and can be perfectly homogeneous. The results of the powder preparation can be seen in Figure 1.

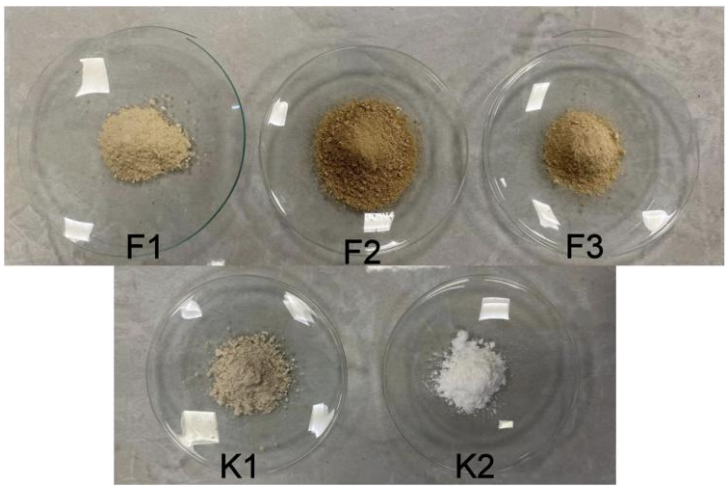

Figure 1. Results of tablet powder preparation.

Table 2. Powder evaluation results

Formula	Moisture Content (%)*	Compressibility (%)	Angle of Repose (°)	Flow Rate (g/second)
F1	3.77 ± 0.20	5.99 ± 0.01	31.66 ± 0.36	13.38 ± 0.05
F2	4.69 ± 0.10	5.99 ± 0.01	31.52 ± 0.31	13.37 ± 0.05
F3	4.29 ± 0.11	6.99 ± 0.02	30.25 ± 0.20	18.62 ± 0.14
K1	5,16 ± 0.17	18.00 ± 0.06	7.49 ± 0.30	1.34 ± 0.03
K2	3.57 ± 0.19	15.82 ± 0.05	13.74 ± 0.12	3.53 ± 0.07

*numeric data presented with three replications as mean±SD, standard deviation.

The fundamental differences in the powder preparation results are the powder's color and aroma. The test formula groups (F1, F2, F3) have a darker color and a stronger aroma, and the higher the ratio of PBN used in the co-processed excipient, the darker the color and the stronger the smell of the powder. Meanwhile, the control groups (K1 and K2) have a lighter color even though K1 uses PBN alone as the tablet excipient. It is because the test formulas use the co-processed excipient, which is obtained from the spray drying process involving heating, resulting in a darker color. It is consistent with the research by Masruroh *et al*. (2021), which states that starch will react and produce a brown color when subjected to heating processes. Additionally, the study by Saputra *et al*. (2023) also explains that heating processes can cause the change in color of starch to a darker shade, changes in pH, and oxidation during storage.

Powder Evaluation Results

The evaluation conducted on the tablet powder includes tests for moisture content, compressibility, angle of repose, and powder flow rate. The obtained results can be seen in Table 2.

Moisture Content Test Results

Moisture content testing on tablet powder is important to produce tablets with good physical properties. The moisture content in the powder is a crucial factor affecting granule quality, the chemical stability of the ingredients, and the potential for microbial contamination. Data in Table 2 show that F1, F2, F3, and K2 have good moisture content, which is <5% (Khasanah *et al*., 2023). Meanwhile, formula K1 with a single Jackfruit Seed Starch (PBN) excipient does not meet the requirement. Excess moisture content can result in stronger particle bonding because the contact area between powder particles increases. If the attractive force between powder particles strengthens, the powder will flow more difficultly and be more challenging to compress.

Conversely, a moisture content that is too low in the powder will cause the formed tablets to be more brittle (Rahmayanti *et al*., 2021). The higher the concentration of Avicel® PH 101 in the co-processed excipient, the lower the moisture content of the powder. Conversely, the higher the concentration of PBN in the co-processed excipient, the higher the moisture content of the powder. Starch has hygroscopic properties and relatively high moisture content, around ±12-18%, while Avicel® has a relatively low moisture content, <5% (Sheskey *et al*., 2020).

The results are consistent with the research by Kartika *et al*. (2012), who found that increasing the concentration of starch can increase the moisture content of granules or powder. It is also consistent with the research by Halim *et al*. (2020), stating that the higher the concentration of Avicel® PH 101, the lower the moisture content, whereas the higher the concentration of purple sweet potato starch, the higher the moisture content.

Compressibility Test Results

The compressibility test is conducted to ensure flow characteristics, determine powder density, which affects its bulk mass, and ascertain the reduction in volume with each compression stroke during the powder compaction process. Particle size and powder density are two variables that influence compressibility outcomes (Shen *et al*., 2022). Based on Table 2, it can be seen that all formulas, including F1, F2, F3, K1, and K2, have good compressibility values, i.e., <20% (USP, 2002; Durga *et al*., 2020; Zhao *et al*., 2022).

From the data of the powder compressibility results, it can be observed that the test formula groups (F1, F2, and F3) have almost similar values because the spherical shape of the powder and the particle size of the co-processed excipient dominate in the formula, resulting in nearly uniform volume reduction with each compression stroke. It is consistent with the research by Rahmayanti (2021), which explains that powders with spherical shapes are usually easier to self-arrange, thus reducing the compaction index or compressibility index. On the other hand, the control formula groups (K1

and K2) yield significantly higher compressibility values compared to the test formula groups because they use fine powders of Avicel® PH 101 and jackfruit seed starch as single excipients, which have tiny particle sizes, leading to more significant volume reduction with each compression stroke. It corresponds to factors influencing compressibility values, namely particle size and powder density (Shen *et al.,* 2022). The compressibility value of K1 is higher than K2 because the particle size of Jackfruit Seed Starch (PBN) is smaller than that of Avicel® PH 101. This is in accordance with Sheskey *et al.* (2020) that PBN has a particle size of around 100µm and Avicel® PH 101 has a particle size of 50µm.

Repose Angle Test Results

The angle of repose test on the powder is conducted to ensure the powder's or granules' flow characteristics. The requirement for a good angle of repose value is 25-35° (USP, 2002; Durga *et al*., 2020; Mamagkaki *et al*., 2021). The data obtained in Table 2 shows that formulas K1 and K2 do not meet the good angle of repose requirement. This is mainly due to the size and shape of the powder which organoleptically looks very small and fine. In contrast, formulas F1, F2, and F3 have larger powders. These results are consistent with the research by Laili *et al*. (2017), which found that tablet powder with a co-processed excipient ratio of starch-avicel at 1:4, 2:3, 3:2, and 4:1 produces good flow properties with the angle of repose values among the formulas not differing significantly, around 30-31°.

Flow Rate Test Results

Flow rate testing is conducted to ensure the flow characteristics of the powder or tablet. From the data obtained in Table 2, it can be seen that the test formulas (F1, F2, and F3) show results that meet the criteria, namely 4-10 grams/second with a good category and >10 grams/second with a very good category (Putri *et al*., 2022; Khasanah *et al*., 2023). These results are due to the excipient used in the tablet formula, the co-processed excipient PBN-A, which organoleptically has a larger powder size than the initial raw material powder, thus allowing good flow. In the research by Syofyan *et al*. (2013), tablet powders using co-processed starch-avicel excipients showed very good flow rates ranging from 10-14 grams/second. In contrast, the control formulas, K1 and K2, do not meet the good criteria for powder flow rate, primarily due to the very small and fine particle size and shape of the powder. These results are consistent with Okunlola (2018) statement that powders with fine particles have high cohesion and thus cannot flow well.

Tablet Results

The results of vitamin C tablets with the co-processed excipient combination of PBN and Avicel PH® 101 show differences in color and aroma, which can be seen in Figure 2. The results obtained regarding the color, aroma, and taste of the tablets are similar to the preparation of the tablet powder. Meanwhile, the shape of the tablets produced is round and compact, except for Control 1, where tablet damage occurred, namely surface crumbling. Crumbling in tablets can occur due to insufficient pressure during compression and a lack of binding agents. The crumbling in K1 can be attributed to the lack or absence of binding agents in the tablet formula. These results are consistent with the study by Wicaksono and Syifa' (2008), which found that using cassava starch as a single excipient in direct compression tablet formulas resulted in less compact tablets with the lowest hardness.

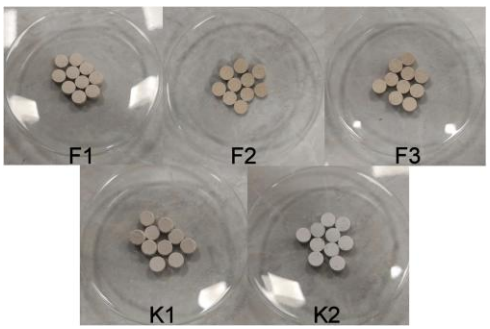

Figure 2. Results of tableting

Tablet Physical Evaluation Results

The physical evaluation conducted on the tablet includes tests for weight uniformity, size uniformity, hardness, friability, and tablet disintegration time. The results obtained can be seen in Table 3.

Tablet Weight Uniformity Test Results

The weight uniformity test is conducted to ensure the extent of weight variation in each tablet, and the results of this variation are correlated with the dosage of each tablet. Good weight uniformity for tablets (uncoated and film coated) with a weight of 80-250 mg is a maximum percentage deviation for each tablet of 7.5% from the average tablet (EEC, 2020).

Based on the results obtained in the Table 3, the K1 and K2 formula does not meet the requirements with one tablet out of 20 deviating by more than 7.5%, while the other formulas meet the requirements. It is consistent with the research by Mohammed (2014), which states that the ratio of starch to MCC in a co-processed excipient does not affect tablet weight. It also aligns with the findings of Kartika *et al*. (2012), who produced uniformly weighted tablets with minimal differences between formulas despite differences in the concentration of starch and Avicel® PH 101.

Tablet Uniformity Test Results

The size uniformity test is a tablet formulation test aimed at ensuring the consistency of size in each tablet. The size of tablets is indicated by the ratio of diameter to thickness. Based on the results obtained, all formulas meet the size uniformity requirements, meaning the diameter of each tablet should be at most three times or less than 4/3 times its thickness (Kemenkes RI, 2020). The results are consistent with the findings of Mohammed (2014), indicating that the starch-MCC ratio in a co-processed excipient as a direct compression tablet excipient does not significantly affect size uniformity.

Tablet Hardness Test Results

Tablet formulations must have a certain hardness as required to withstand various treatments from the manufacturing process (tablet compression), packaging, and transportation (distribution) to the consumption stage. The strength or hardness of the final tablet is influenced by the compression force, the particle size of the powder, and the properties of the materials used in the formula. Based on the data obtained, only F1 meets the criteria, while F2, F3, K1, and K2 do not meet the criteria. Especially K1 has a tablet hardness of 0.00 because the tablets obtained are very fragile and easily crushed. The requirement for tablet hardness is 4-8 kg (Abdul-Hasan *et al*., 2022; Nugraheni *et al*., 2023). From the tablet hardness data, it is evident that increasing the proportion of avicel® PH 101 used in the co-processed excipient makes the tablets harder. In F2 and F3, the tablet hardness does not meet the criteria. It could be due to the properties of the formulation, where F2 and F3 are formulations with a co-processed excipient with a more significant or equal proportion of jackfruit seed starch to avicel® PH 101.

In this formulation, the ratio of Avicel® PH 101 in the co-processed excipient used as a filler-binder significantly affects the tablet hardness because avicel® PH 101 acts as a binder. Based on the statistical test results, a significance value of 0.000 was obtained, which is <0.05. It indicates that the data obtained have a significant difference. In the LSD test, it was stated that the test formulas (F1, F2, F3) differed significantly from the control formulas (K1, K2). It is consistent with the research by Wicakno and Syifa' (2008), which stated that tablet hardness significantly increases with the increasing amount of Avicel® PH 101 in the co-process.

Table 3. Physical evaluation results of the tablet

Formula	Tablet Weight (mg)*	Thickness of Tablets (mm)*	Diameter of Tablets (mm)*	Tablet Hardness (Kg)*	Tablet Friability (%)*	Tablet Disintegration Time (minutes)*
F1	205.80 ± 7.32	2.90 ± 0.09	8.15 ± 0.04	4.94 ± 0.33	0.45 ± 0.00	0.79 ± 0.12
F2	203.75 ± 7.85	3.04 ± 0.14	8.23 ± 0.07	2.28 ± 0.36	1.18 ± 0.00	3.81± 0.23
F3	212.00 ± 7.69	2.96 ± 0.11	8.24 ± 0.05	3.48 ± 0.68	0.89 ± 0.00	1.87 ± 0.28
K1	205.40 ± 10.38	2.96 ± 0.11	8.19 ± 0.07	0.00 ± 0.00	7.60 ± 0.02	3.79 ± 0.19
K2	204.00 ± 8.16	2.98 ± 0.10	8.21 ± 0.03	9.52 ± 0.73	0.35 ± 0.00	6.81± 0.43

*numeric data presented as mean±SD, standard deviation.

Additionally, Mohammed (2014) stated that increasing the concentration of MCC improves powder binding efficiency, thus increasing tablet hardness.

Tablet Friability Test Results

The friability test determines the tablet's resistance to shock during packaging. The standard for good tablet friability is <1% (USP, 2007; Tafere *et al*., 2021; Alburyhi *et al*., 2023; Nugraheni *et al*., 2023). It can be seen that the highest friability is in K1, which is 7.6%, where this formula does not use a co-processed excipient but only Jackfruit Seed Starch (PBN). The formula that does not meet the criteria is F2, with a ratio of PBN and Avicel® PH 101 of 3:1, where the starch concentration is higher, making it more brittle. Meanwhile, F1, F3, and K2 meet the criteria, which are formulas that use a higher or equal ratio of Avicel® PH 101 to starch.

From the results, the PBN and Avicel® PH 101 ratio in the co-processed excipient can affect tablet friability. The higher the concentration of Avicel® PH 101 in the co-processed excipient, the lower the tablet friability, and vice versa. Based on the one-way ANOVA statistical test, a significance value of 0.000 was obtained, which is <0.05, indicating a significant difference. In the LSD test, it was stated that K1 differs significantly from all formulas, both F1, F2, F3, and K2. These results are consistent with the research by Laili *et al*. (2017), which made tablets with co-process excipients of sago starch and Avicel® PH 101, resulting in increased friability with increasing starch ratio in the co-processed excipient.

Tablet Disintegration Time Test Results

The tablet disintegration test is a test to ensure how long a tablet dissolves completely in the body. The physical properties of granules, porosity, and tablet hardness affect the disintegration time of tablets, where higher tablet hardness values can indicate longer disintegration times. The criteria for good disintegration time for non-modified release tablets are <15 minutes (Markl and Zeitler, 2017; Murtini and Elisa, 2018; Nugraheni *et al*., 2023). Table 3 shows that in formulas using the PBN-A co-processed excipient (F1, F2, and F3), the higher the concentration of PBN in the co-processed excipient, the longer the tablet disintegration time, and vice versa. These results are consistent with the research by Kelana *et al*. (2018), stating that Avicel in the co-processed excipient acts not only as a filler but also as a disintegrant, so with increased avicel concentration in the co-processed excipient, the tablet disintegration time can increase.

In contrast to formulas without co-processed excipients, formulas using only jackfruit seed starch as a single filler dissolve more quickly than formulas using only Avicel® PH 101 as a filler. It could be because Avicel® PH 101's properties as a good filler and binder in a formula, thus leading to longer tablet disintegration times. Additionally, formulas with single Avicel® PH 101 excipients have the highest hardness, which is one of the factors that can affect tablet disintegration time. Based on the one-way ANOVA statistical test, a significance value of 0.000 was obtained, which is <0.05, indicating a significant difference. In the Least Significance Test (LSD) test, it was found that all formulas significantly differ from each other except for F1 and K1, which are not significantly different. It could be because F1 and K1 are formulas with the highest starch concentration as a filler.

CONCLUSIONS

From the conducted research, it can be concluded that direct compression tablets of vitamin C using the co-processed excipient of jackfruit seed starch (*Artocarpus* heterophyllus Lam.) and Avicel® PH 101 with a variation of PBN and Avicel® PH 101 ratio of 1:3 (F1) meet the requirements for good tablet physical characteristics in all evaluations. However, in the ratio of 3:1 (F2), they do not meet the requirements for hardness and friability of the tablets, and in the ratio of 1:1 (F3), they do not meet the criteria for tablet hardness.

ACKNOWLEDGEMENTS

This research was conducted with support and funding from the Bantuan Operasional Perguruan Tinggi Negeri (BOPTN) 2023, Maulana Malik Ibrahim State Islamic University, Indonesia.

CONFLICT OF INTEREST

There are no competing interests for the authors in relation to this investigation.

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