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Literature Review: Optimization Of Tablet Formula With Variations In Binder Type On The Physical Properties Of Tablets

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Abstract

Tablets are a widely used pharmaceutical dosage form due to their stability, dosage accuracy, ease of production, and ease of use. One important factor influencing tablet quality is the use of binders, which play a role in increasing interparticle cohesion and mechanical strength. This study aims to evaluate the effect of varying binder types and concentrations on the physical characteristics and performance of tablets, including hardness, friability, disintegration time, and dissolution profile. The method used was a literature review with a descriptive analytical approach based on scientific articles from indexed journals. The results of the study indicate that the type of binder significantly influences tablet properties. Synthetic binders such as polyvinylpyrrolidone (PVP) and Avicel tend to produce more consistent hardness and lower friability, while natural binders such as starch, gelatin, pectin, and mucilage show wider variation in results depending on the source and process. Increasing binder concentration generally increases hardness and decreases friability, but can prolong disintegration time and decrease dissolution rate. Therefore, optimal tablet formulation is achieved through a balance between mechanical strength and drug release capability, by using binders at optimum concentrations and considering interactions with other excipients and the manufacturing method.

Keywords: ***Formulation, Tablets, Excipients, Binders.***

INTRODUCTION

Tablets are one of the most widely used pharmaceutical dosage forms in therapy due to their various advantages, such as good stability, ease of production, dosage accuracy, and comfort for patients. In tablet development, physical and pharmaceutical quality are important aspects to consider. Parameters such as hardness, friability, disintegration time, and dissolution profile are key indicators in assessing tablet quality. The quality of these parameters is greatly influenced by the formulation composition, particularly the use of excipients, including binders. Binders play a crucial role in forming tablet compactness by increasing cohesion between powder particles, resulting in a stable tablet structure that is resistant to disintegration during production and distribution (Putri & Husni, 2018). A common problem is the imbalance between mechanical strength and drug release capacity, where increased hardness is often followed by decreased dissolution and a slower disintegration time (Roy *et al*., 2025).

This title was chosen based on the importance of binders in determining tablet quality. Furthermore, there is a trend toward using natural materials as alternatives to synthetic binders that are more biocompatible and economical. Various studies have shown that synthetic binders such as PVP and microcrystalline cellulose provide more consistent results, while natural binders such as starch, gelatin, and mucilage have potential but show wider variation in results (Nofriyaldi *et al*., 2020; Wahyudi *et al*., 2024).

Previous research has extensively examined the effect of binder type and concentration on tablet physical properties. The results indicate that increasing binder concentration can increase hardness and decrease friability, but can prolong disintegration time and decrease dissolution at certain concentrations (Sulistyaningrum *et al*., 2018; Roy *et al*., 2025). However, most studies still focus on specific parameters, thus not providing a comprehensive picture of the relationships between tablet quality parameters. This indicates a research gap in comprehensively understanding formulation optimization.

RESEARCH METHODS

This study used a literature review method with a descriptive analytical approach to evaluate the effect of variations in the type and concentration of binders on the physical characteristics and performance of tablets, especially hardness, friability, disintegration time, and dissolution. Data sources were obtained from national and international scientific articles published in indexed journals, including SINTA-accredited journals and scientific databases such as Google Scholar, PubMed, and ScienceDirect. Keywords used in the literature search included: tablet binder, tablet formulation, friability, hardness, disintegration time, and dissolution profile. Inclusion criteria in this study included: articles discussing tablet formulations, especially paracetamol or conventional tablet models, studies using a variety of binders, both synthetic and natural, and articles reporting complete physical evaluation parameters of tablets. Meanwhile, exclusion criteria included articles that did not provide clear experimental data or were not relevant to the focus of the study.

The obtained data were then analyzed qualitatively by comparing results from different studies to identify patterns of relationships between binder type and concentration and tablet characteristics. The analysis was conducted through data reduction, comparative narrative presentation, and systematic conclusion drawing. This approach was used to obtain a comprehensive overview of the role of binders in optimizing tablet formulations.

RESULTS AND DISCUSSION

The results of the study "Differences in Mental Health Literacy in Pregnant Women Based on Socioeconomic Level at the Kembaran 1 Community Health Center, Banyumas Regency" were conducted in October 2025 with a sample of 93 respondents. The results are described in the table below:

No	Author & Year	Article Title	Types of Binders	Evaluation test results			
				Violence	Friability (fragility)	Dissolution	Time is destroyed
1.	Sulistriyani *et al*., (2022).	THE EFFECT OF CHITOSAN CONCENTRATION VARIATIONS AS AN INGREDIENT DESTRUCTORS ON THE PHYSICAL PROPERTIES OF ORALLY DISINTEGRATING PREPARATIONS Paracetamol Tablets (ODT)	Avicel pH 102	4.4–5.4 kg (qualified)	0.266–0.457% (<1%, good)	95.06–99.56% (>80%, meets)	24–262 seconds (F1 & F2 satisfied, F3 not)
2.	Rosmayati *et al*., (2023)	Evaluation of Excipients as Binders for Paracetamol Tablets	Tamarind seed starch (5% & 10%)	F1: 4.6 kg F2: 7.5 kg F3: 6.3 kg F4: 8.9 kg (not meeting)	F1: 1.41% (not met) F2: 1.00% F3: 0.99% F4: 0.77%	F2: 15.44% (not eligible ≥80%)	F1: 29.87 minutes F2: 47.94 minutes (not met) F3: 4.89 minutes F4: 8.94 minutes (fulfilled)
3.	Sipatu & Ani, (2024)	Paracetamol Tablet Formulation Using Durian Seed Starch (Durio zibethinus *Murr*) as a Direct Compression Binder	Durian seed starch (8%, 10%, 12%)	Fulfill (±4–8 kg); no significant difference between formulas	Meets (<1%); range ±0.40–0.60%	FI (8%): meets (>80%/30 minutes); FII & FIII: does not meet	All meet
4.	Cahyani *et al*., (2023)	Paracetamol Tablet Formulation with PVP Combination And Porang Tubers Starch (Amorphopallus onchopyllus) As Material Binders Against Physical Properties of Tablets	PVP (Polyvinylpyrrolidone) + Porang Tuber Flour (Glucomannan)	F1: 7.30 kg (fulfilled) F2: 14.37 kg F3: 8.88 kg F4: 10.09 kg	F1: 0.21% F2: 0.12% (all meet <1%)	fulfil	F1: 9.6 minutes (qualified) F2–F4: >15 minutes (not met)
5.	Komariyatun & Hidayati, (2021)	Paracetamol Tablet Formulation Using Kepok Banana Stem Flour (Musa Paradisiaca CV. Kepok) as a Binder.	Kepok banana stem flour (Musa paradisiac)	2.79 – 5.28 kg (FI–FV) (FI & FII do not meet, FIII–FV meets the requirements 4–8 kg)	6.7 – 38.4 % (not eligible <1%)	59.4 – 79.1 % (does not meet requirements ≥80%)	0.7 – 1.85 minutes (meets the requirement of <15 minutes)

6.	Nurhabibah *et al*., (2023)	The Effect of Using Chicken Feet Gelatin and Commercial Beef Feet Gelatin As a Binder in Paracetamol Tablet Formulation	Chicken and beef feet gelatin	4.22 – 7.4 kg (qualifies 4–8 kg)	0.31 – 0.59% (<1%, meets)	62.31 – 98.32% (some meet ≥80%)	1.44 – >15 minutes (some do not meet because F6 >15 minutes)
7.	Zilhadia *et al*., (2021)	Preparation and evaluation on paracetamol tablets using goatskin gelatin as a new binder.	Goat skin gelatin	F1: 12.25 Kp F2: 13.84 Kp F3: 15.07 Kp (Not eligible)	F1: 0.74% F2: 0.68% F3: 0.62% (qualified)	F1: 96.12% F2: 98.45% F3: 99.78% (qualified ≥80%)	F1: 5.21 minutes F2: 4.32 minutes F3: 3.71 minutes (qualified)
8.	Sulistyaningrum *et al*., (2018)	The Effect of White Sweet Potato Starch (Ipomoea batatas L) Concentration as a Binder on the Physical Properties of Tablets and Paracetamol Dissolution	White sweet potato starch	F1: 8.19 kg (Meets the requirements 4-8kg) F2: 13.49 kg F3: 15.13 kg F4: 15.07 kg F5: 15.61 kg (Not eligible 4-8 kg)	F1: 0.3% F2: 0.6% F3: 0.4% F4: 0.5% F5: 0.6% (Eligible <1%)	F1: 85.27% F2: 84.17% F3: 80.43% (F1, F2, and F3 meet the requirements> 80%) F4: 78.02% F5: 75.88% (F4 and F5 Not eligible)	F1: 13 minutes F2: 14 minutes (F1 and F2 meet the requirements < 15 minutes) F3: 19 minutes F4: 23 minutes F5: 25 minutes (F3, F4, and F5 are not eligible)
9.	Kosasih, K., Mayasari, M., & Gusmayadi, I. (2025)	Development of Paracetamol Tablet Formulations Using Phosphate-Pregelatinized Cornstarch as Binders	Phosphate-pregelatinized Zea mays starch	5.8 kg (qualified)	0.5% (<1%, meet)	99.28% (>80%, meets)	1.36 minutes (<15 minutes, meet)
10.	Tessema, TA, Kassa, FM, & Joseph, N.M. (2025)	Characterization and evaluation of the fruit mucilage of Cordia africana as tablet binder in paracetamol tablet formulation	Mukilago fruit of Cordia africana	<100 N (qualified)	0.63% (<1%, meet)	83.3% (>80%, meets)	0.55-10.27 minutes (fulfilled)
11.	Dhamdhere, JK (2024)	Formulation and evaluation of paracetamol tablets using natural binders	Aliv powder & basil	±3.6-3.9 kg (less than optimal, some do not meet 4–8 kg)	0.2-0.7% (<1%, meet)	±54-85% (basil meets, aliv does not)	±11-14 seconds (very fast filling)
12.	Fegade, *et al*., 2023	Formulation and Evaluation of Paracetamol Tablets Using Pectin as Binder	Pectin (Limonia acidissima)	±4 – 6 kg (Meets the requirements of 4-8 kg)	±0.5 – 0.9% (Eligible <1%)	82 – 88% (Meets requirements >80%)	±5 – 10 minutes (Qualified <15 minutes)
13	Ugoeze, K.C., Nwachukwu, N., & Okeke, C.E. (2021).	The physico-chemical and filler-binder-disintegrant properties of improved hydrophilic powder derivative ophilic powder derived from the fiber om the fiber of Ipomoea e of Ipomoea batatas tuber in paracetamol tablets	Hydrophilic Powder (HP) from Ipomoea batatas fiber	Hardness meets pharmacopoeial requirements (strong enough, not brittle)	<1% (qualified)	78.65% (wet granulation) 81.44% (direct compression) meets the requirements of ≥80%	< 30 seconds fast disintegrating tablet
14	Dauda, U., Khalid, GM, Musa, H., Bhatia, PG, Hassan, MA, Yola, AU, & Ilyasu, S.	Binder and disintegrant performance of native and thermally modified Dioscorea cayenensis starches	UMS (Unmodified starch / natural starch), PGS1 (pregelatinized starch), PGS2 (ethanol	PGS2 produced tablets with the highest (significant) hardness.	UMS > 3% (not eligible) PGS1 & PGS2 → lower (better)	PGS1 fast (IR), PGS2 slow (SR)	Fulfill (<15 minutes)

	(2019).	in paracetamol tablet formulations.	pregelatinized starch)				
15	Kumereshwaran , D.D., & Rahman, S.A. (2024).	Formulation and Evaluation of Paracetamol Tablets Using Konjac Glucomannan as Natural Halal Binder	Konjac Glucomannan (KGM) Used in variations: 5%, 10%, 15%, 20%	Meets USP standards	Only F4 (20% KGM) is eligible (<1%)	Not listed (good indication)	Meets USP standards < 15 minutes (uncoated tablet)

Discussion

The Role of Binders in the Physical Characteristics of Tablets

In tablet formulation, physical characteristics such as hardness, friability, and disintegration time are significantly influenced by the composition of the excipients used, one of which is the binder. This additive plays a specific role in tablet formulation as a unifier, or in other words, a binding agent, to unite the tablet contents to form a good compact. The binder ensures the unification of several powder particles into a granulate. Tablet compactness is influenced not only by compression pressure but also by the binder (Putri & Husni, 2018).

Good granulation results will support tablet compactness based on the binder used, which can be synthetic or semi-synthetic and natural polymers. Meanwhile, synthetic and semi-synthetic materials include vinyl pyrrolidone derivatives, modified starch, and cellulose. Among them, some of the most frequently used are sodium carboxymethyl cellulose, ethyl cellulose, methyl cellulose, copovidone povidone (polyvinylpyrrolidone, PVP, hydroxypropyl cellulose, hydroxypropyl methyl cellulose. In general, based on the use of binders, the higher the concentration of the binder solution added during the tablet production stage, the higher the viscosity. This can reduce the contact angle, increase granule size and surface tension, and reduce brittleness in the tablet. However, the goal of tablet formulation is not to produce tablets that are as hard as possible, but rather tablets with good levels of brittleness and hardness that are close to the standard, with the use of binders (Nur'assyfa *et al*., 2024).

Based on the results of a review of various studies that have been reviewed, the types of binders used in tablet formulations show quite wide diversity, including both synthetic and natural materials. Commonly used synthetic binders include Avicel pH 102 and polyvinylpyrrolidone (PVP), which are known to have good compressibility and binding properties. On the other hand, natural binders used in various studies include starches from various plant sources such as tamarind seed starch, durian seed starch, pregelatinized corn starch, and sweet potato starch. In addition, other natural ingredients such as gelatin, pectin, fruit mucilage, konjac glucomannan, and plant fibers are also widely used as alternative binders in tablet formulations (Nofriyaldi *et al*., 2020).

This diversity of binding agents demonstrates a growing trend toward utilizing natural materials as alternatives to synthetic binders, particularly in developing more biocompatible, natural-based pharmaceutical preparations. Natural binders generally come from polysaccharides and proteins, which have the ability to form matrices and increase interparticle cohesion, although their characteristics are strongly influenced by the source material and processing method. Meanwhile, synthetic binders tend to have a more uniform structure and properties, making them frequently used as comparators in various tablet formulation studies (Suparman *et al*., 2021).

Overall, the variety of binder types used in various studies demonstrates that binder selection is based not only on material availability and desired needs, but also on physicochemical properties and potential interactions with other components in the formulation. This is therefore an important basis for tablet development, as the type of binder used will play a role in determining the overall quality and performance of the preparation.

Variations in Binder Types and Their Relationship to Tablet Mechanical Strength

Based on the results of various studies that have been conducted, variations in the type of binder in tablet formulations provide different contributions to the mechanical strength of tablets, especially in hardness parameters. Variation in the type of binder in tablet formulations is one of the

crucial aspects that contribute to differences in the mechanical strength characteristics of the preparation. Based on the review of various studies, the selection of the type of binder, whether derived from synthetic or natural materials, shows differences in the ability to form a compact and stable tablet structure. These differences are closely related to the physicochemical properties of each binder, such as adhesion and cohesion capabilities between particles, plasticity, and its potential interaction with other components in the formulation system (Putri & Husni, 2018).

Hardness testing is crucial for determining the best binder characteristics for each reviewed journal. All formulations used in this hardness test must meet the tablet hardness requirements of 4-8 kg. Different binder types certainly produce varying results in hardness tests, necessitating further research and analysis of each binder's use. Furthermore, variations in the binder concentration used in each study also reinforce the differences in contribution to tablet mechanical strength. This suggests that not only the type but also the proportion of binder used is a determining factor in tablet characteristics (Saryanti, 2019).

Based on the results of the review of various studies, it can be identified that several types of binders are able to produce optimal mechanical strength of tablets, while other types show results that do not meet the established standards. Synthetic binders such as Avicel pH 102 and PVP combinations show a tendency to produce tablet hardness values that are within the range that meets pharmacopoeial requirements, so they are considered capable of providing good compactness in tablet preparations. In addition, several natural binders such as durian seed starch, pregelatinized corn starch, and pectin are also reported to be able to produce tablet hardness that meets standards, especially at certain concentrations.

On the other hand, several types of binders showed less than optimal hardness results or did not meet requirements. The use of natural ingredients such as banana stem flour, tamarind seed starch in certain formulas, and several types of gelatin showed significant variation in results, with some formulations producing hardness values outside the standard range. Furthermore, the use of high concentrations of sweet potato starch and several other types of natural binders also tended to produce excessive or unstable hardness.

Overall, these identification results indicate that the ability of a binder to produce mechanical strength in tablets is significantly influenced by the type of material used and its concentration in the formulation. Binders with more controlled structures and properties tend to provide more consistent results, while natural binders exhibit wider variations, requiring further testing to achieve optimal tablet hardness, such as dissolution and friability testing (Banne *et al*., 2021)..

Tablet Friability Characteristics in Various Binder Formulations

Tablet friability is an important parameter in tablet quality evaluation, indicating the tablet's ability to maintain its physical integrity when subjected to mechanical stress during production and distribution. This test is performed by measuring the percentage of tablet weight loss after being rotated in a friabilator under certain conditions. Generally, the accepted limit is less than 1%, indicating the tablet has good mechanical resistance and is not easily damaged. A high friability value indicates weak interparticle bonds in the tablet, resulting in an unstable structure. This parameter is influenced not only by compression pressure but also by the type and nature of the binder used. In addition, particle size and granule distribution also determine tablet cohesiveness. Therefore, friability is an important indicator in assessing the overall physical quality of a tablet (Guntilake *et al*., 2016).
Based on the compiled results in the table, most paracetamol tablet formulations showed acceptable friability values. The use of binders such as PVP, gelatin, and modified starch resulted in tablets with low friability. This indicates that these materials are able to effectively increase interparticle cohesion during the compression process. The resulting tablets have a more compact structure and are less prone to abrasion. In addition, low friability values also indicate the mechanical stability of the tablets during the distribution process. Differences in binder types contribute to variations in the results obtained. This demonstrates the importance of selecting binders in tablet formulations (Roy *et al*., 2025).

The relationship between friability and tablet hardness has been quite consistent across various studies. Tablets with higher hardness generally exhibit lower friability values. This occurs because interparticle bonds become stronger due to optimal compression pressure. The tablet structure becomes denser, making it less susceptible to mechanical damage. When using PVP, the ability to form hydrogen bonds significantly improves tablet cohesiveness. However, this increase in hardness needs to be controlled to avoid affecting other parameters. Excessive hardness can slow the tablet disintegration process (Wahyudi *et al*., 2024).

Not all binders provide optimal results for friability. In some natural-based formulations, friability values can increase significantly. This is related to the material's less plastic nature and inability to deform well during compression. As a result, interparticle bonds become weak and tablets are susceptible to damage. Furthermore, non-uniform particle size distribution can also deteriorate tablet quality. A less homogeneous granule structure causes tablets to be more brittle. This condition indicates that material characteristics significantly affect tablet quality (Wandira *et al*., 2023). Binder concentration has a significant influence on tablet friability. At low concentrations, the amount of binder is insufficient to form strong cohesion between particles. This causes the tablet to be susceptible to abrasion and loss of mass. Conversely, increasing binder concentration can significantly decrease friability values. Tablets become more compact and mechanically stable. However, using excessive amounts can cause tablets to be too dense and hard. This condition can impact other parameters such as disintegration and dissolution time (Krisdivayanti *et al*., 2024).

Different types of binders also influence the mechanical characteristics of tablets. Synthetic binders, such as PVP, tend to produce more consistent results than natural binders. This is due to their plastic properties and better deformation ability during compression. These materials are able to form a strong and stable matrix. In contrast, natural materials often exhibit variations in results depending on the source and processing method. Differences in chemical composition affect binding ability, resulting in inconsistent results (Roy *et al*., 2025). Some natural materials, such as gum and mucilage, show potential as alternative binders. These materials are hydrophilic and capable of forming gels upon contact with water. This ability can increase interparticle cohesion and reduce friability. The resulting tablets retain good mechanical strength. However, results often vary due to differences in material composition. The extraction and purification processes also affect the quality of these materials. This highlights the need for standardization in the use of natural materials (Sipatu & Aini, 2023).

Tablet friability is influenced by a combination of factors such as binder type, concentration, and mechanical properties. Synthetic and modified binders tend to produce tablets with lower friability. Meanwhile, natural materials require further optimization to achieve consistent results. Interactions between parameters such as hardness and granule structure also play a significant role. Tablets that are too hard do not always perform optimally. A balance between mechanical strength and other properties is essential. This suggests that tablet formulations must be designed comprehensively (Nurwahid *et al*., 2024).

Dissolution Profile as a Performance Indicator of Tablet Formula

Dissolution is a crucial parameter in tablet evaluation, describing the ability of the active ingredient to dissolve in a medium within a specified time. This parameter is directly related to drug bioavailability because the active ingredient must dissolve before it can be absorbed by the body. Testing is conducted under controlled conditions to simulate a physiological environment. The general standard for immediate-release tablets is a minimum release of 80% within 30 minutes. A low dissolution value may indicate a potential decrease in therapeutic efficacy. Formulation factors significantly influence dissolution results. Therefore, this parameter is a key indicator in tablet evaluation (Herline *et al*., 2020). Based on the data in the table, most formulations demonstrated dissolution values that met the standard. The use of binders such as PVP, gelatin, and modified starch resulted in high release of the active ingredient. In fact, some formulations demonstrated dissolution rates approaching 100%. This indicates that the binder did not inhibit drug release. The tablet was able

to interact optimally with the medium. The release of the active ingredient occurred quickly and evenly. These conditions reflect good formulation quality (Sipatu & Aini, 2023).

The hydrophilic properties of binders play a significant role in enhancing dissolution. Water-absorbing materials accelerate the penetration of the medium into the tablet. This process accelerates disintegration and increases the contact surface area of the active ingredient. PVP is known to effectively enhance particle wetting. This contributes to an increased rate of drug dissolution. This property is crucial in immediate-release tablet formulations. The selection of materials with hydrophilic characteristics is a key factor (Lestari & Okana, 2025). Some formulations exhibit dissolution values that do not meet requirements. This typically occurs in tablets with excessive compactness. Tablets that are too dense have low porosity, which hinders liquid penetration. The disintegration process is slower and drug release is delayed. This condition indicates that high mechanical strength is not always beneficial. The relationship between hardness and dissolution is not always linear. Other factors such as matrix structure also play a role (Wandira *et al*., 2023).

Tablet hardness is closely related to the dissolution profile. Tablets with higher hardness tend to exhibit slower dissolution rates. This is due to their denser structure and increased permeability to the medium. In several studies, increasing binder concentrations resulted in decreased dissolution. The interaction between porosity and diffusion is a major factor in this phenomenon. This situation highlights the importance of balance in formulation. Not all increases in mechanical strength yield positive results (Roy *et al*., 2025).

The viscosity of the binder also affects tablet dissolution. Some materials can form a gel layer upon contact with water. This layer can inhibit the diffusion of the active ingredient into the medium, resulting in slower drug release. This phenomenon often occurs in materials with strong matrix-forming properties. The gel layer acts as a diffusion barrier. This indicates that the rheological properties of the material need to be considered (Nurwahid et al., 2024).

Disintegration time is directly related to dissolution. A tablet that disintegrates quickly increases the surface area of the active ingredient. This accelerates the dissolution process in the medium. Conversely, a long disintegration time slows dissolution. This parameter demonstrates a close relationship between the physical properties and pharmaceutical performance of tablets. Small changes in formulation can significantly affect results. Therefore, a thorough evaluation must be carried out (Roy et al., 2025). The dissolution profile is influenced by various factors such as the type of binder, hardness, porosity, and disintegration time. Binders that are hydrophilic and do not form too dense structures provide better results. The use of binders with high binding strength in large quantities can decrease the dissolution rate. The balance between mechanical strength and drug release is a crucial aspect in formulation. The interaction between these parameters must be considered simultaneously. This indicates the importance of formulation optimization (Guntilake et al., 2016).

Disintegration Time Dynamics in Tablet Systems with Binder Variations

Tablet disintegration time is a parameter that indicates how quickly the tablet breaks into small pieces after being exposed to a liquid medium, so that the active ingredient can be immediately released, and this parameter is greatly influenced by the type and concentration of the binder because a binder that is too strong will compact the tablet structure and inhibit water penetration into the tablet matrix (Sulistyaningrum et al., 2018). In the study of white sweet potato starch, increasing the binder content showed a tendency for longer disintegration times, so that formulas with higher concentrations are not always the best choice because the tablet is more compact, but the disintegration process becomes slower (Sulistyaningrum et al., 2018). This emphasizes that tablet strength and disintegration speed must be considered simultaneously, not separately as if one is always more important.

A similar pattern was also seen in gelatin-based binders. In goatskin gelatin, Zilhadia *et al*. (2021) showed that increasing binder concentration resulted in better tablet cohesiveness, but the optimum formula still needed to be found because tablets that were too dense would be more difficult to disintegrate. The results were evident from the disintegration time, which still met the requirements for the best formula, namely 3.71 minutes. Therefore, a good binder is not only one that is capable of forming a hard tablet, but also one that still allows water to enter quickly enough to disintegrate the

tablet (Zilhadia *et al*., 2021). Similar findings were also consistent with commercial chicken foot gelatin and cow foot gelatin, where increasing the cohesive strength of the granules tended to prolong the disintegration time in some formulas (Nurhabibah *et al*., 2023).

In starch- and pectin-based binders, the tendency to slow disintegration time is also increasingly evident. Rosmayati *et al*. (2023) showed that tamarind seed starch can be used as a binder, but some formulations resulted in significantly longer disintegration times, making optimization crucial to prevent overcompacting of the tablets. Fegade *et al*. (2023) also found a similar pattern with Limonia acidissima pectin, where the higher the pectin content, the longer the tablet lasted before breaking, although the optimum formulation remained at a certain, balanced concentration. On the other hand, Komariyatun and Hidayati (2021) demonstrated that kepok banana stem flour can indeed be used as a binder, but the physical properties of the tablets remain highly dependent on the ingredient content and the granule formation method.

Not all journals indicate a slowdown in disintegration time, as some studies actually discuss systems designed for rapid disintegration. Sulistriyani *et al*. (2022) showed that in paracetamol ODT tablets, disintegration time can reach seconds to minutes, confirming that rapid-disintegration tablet systems require a highly water-permeable structure. Cahyani *et al*. (2023) also showed that the combination of PVP and porang tuber starch significantly affected disintegration time, and only certain formulas remained within the ideal limits, so the interaction between binder and disintegrant should not be ignored. Thus, disintegration time is not only determined by the binder, but also by the overall design of the formula and the purpose of the preparation (Sulistriyani *et al*., 2022).

In binders that have been modified or further processed, disintegration time can be maintained well without excessively sacrificing tablet strength. Kosasih *et al*. (2025) showed that phosphate-pregelatinized cornstarch was able to produce tablets with hardness, friability, dissolution, and disintegration time that all met the requirements, so that modified starch proved easier to optimize than ordinary natural binders. Tessema *et al*. (2025) also showed that mucilage from Cordia africana fruit could still provide disintegration time within the acceptable range, but the results were still greatly influenced by mucilage content, disintegrant, and compression force. Both of these studies indicate that modified binders tend to provide a better balance between tablet stability and disintegration ability.

Looking further, Dhamdhere (2024) showed that certain natural binders can still produce viable tablets, but their performance must still be interpreted in conjunction with other parameters because good results in one aspect do not necessarily mean good results in all aspects. Ugoeze *et al*. (2021) showed that hydrophilic powder from Ipomoea batatas fibers gives fast-disintegrating tablets, while Dauda *et al*. (2019) showed that natural starch and modified starch from Dioscorea cayenensis can exhibit different behaviors in accelerating or slowing tablet disintegration. Kumereshwaran and Rahman (2024) also emphasized that konjac glucomannan can function as a natural binder, but its concentration must still be controlled to prevent the tablet from becoming too dense. So, the common thread is clear: the best disintegration time occurs when mechanical strength and water penetration ability are in the right balance.

Synthesis of Results and Optimization Strategy of Tablet Formula

Overall, the fifteen journals show that binders play a central role in the quality of paracetamol tablets, but no single binder is consistently superior for all parameters. In studies of white sweet potato starch, goat skin gelatin, chicken and cow feet gelatin, Limonia acidissima pectin, and plantain stem flour, increasing the binder content often improves tablet cohesiveness, but at a certain level it actually prolongs disintegration time and decreases dissolution because the liquid medium has difficulty entering the tablet structure. Thus, the best results are not determined by the highest hardness, but by the balance between the most stable and most functional parameters.

In the starch- and natural fiber-based binder groups, a fairly consistent pattern emerged, with medium concentrations often providing the most balanced results compared to concentrations that were too low or too high. Rosmayati *et al*. (2023) demonstrated that tamarind seed starch can function as a binder, but the performance of each formula differed, requiring optimization to ensure tablets

were neither too hard nor too slow to disintegrate. Sipatu and Ani (2024) also demonstrated that durian seed starch can be used as a binder in direct compression, but not all formulas produced equally good dissolution and compaction performance. The results of Ugoeze *et al*. (2021) and Dauda *et al*. (2019) further emphasize that fiber- or starch-based materials can serve dual functions as fillers, binders, or disintegrants, so their characteristics must be understood before formulation.

In the protein-based binder group, especially gelatin, the theoretical pattern also remains the same: the higher the binder concentration, the more compact the tablet, the lower the friability, but the potential for prolonged disintegration time. Zilhadia *et al*. (2021) showed that goat skin gelatin can produce paracetamol tablets with high dissolution and still good disintegration time, so this material has the potential to be an effective natural binder. Nurhabibah *et al*. (2023) added that commercial chicken foot gelatin and cow foot gelatin are also suitable for use, but the best formula must still be determined based on a combination of all quality parameters, not just one test result. This means that protein binders have great potential, but the concentration must still be maintained to avoid making the tablet too dense and difficult to disintegrate.

In specially modified or developed binders, optimization opportunities appear greater because their physicochemical properties are specifically geared toward supporting tablet performance. Kosasih *et al*. (2025) demonstrated that phosphate-pregelatinized cornstarch is capable of producing formulas with adequate hardness, low friability, high dissolution, and short disintegration times, making this modified starch easier to optimize than conventional natural binders. Tessema *et al*. (2025) also demonstrated that mucilage from the fruit of Cordia africana has potential as a binder, but the best results still depend on the combination of mucilage concentration, disintegrant, and compression force. In Kumereshwaran and Rahman (2024), konjac glucomannan as a natural halal binder also showed that increasing binder concentration can improve tablet integrity, but must be maintained so that friability and disintegration times remain within acceptable limits.

In addition to the binder type, other factors such as the tablet manufacturing method and the presence of disintegrants should also be considered because several journals show that fast-disintegrating tablet systems do require a different design than regular tablets. Sulistriyani *et al*. (2022) showed that paracetamol ODT tablets can disintegrate very quickly because they are formulated to disintegrate quickly, while Cahyani *et al*. (2023) showed that the combination of PVP and porang tuber starch only produces good disintegration times in certain formulas. Dhamdhere (2024) also emphasized that the use of natural binders can still produce viable tablets, but the results should not be judged solely on one parameter because strength, friability, dissolution, and disintegration time must be considered together. Therefore, a good optimization strategy always matches the type of binder to the intended use.

Based on all the reviewed journals, the most rational optimization strategy for paracetamol tablets is to select a binder at a medium concentration, then adjust it to the manufacturing method, type of disintegrant, and target quality of the preparation. At too low a concentration, tablets tend to be brittle and less stable, as seen in studies by Komariyatun and Hidayati (2021) and Dhamdhere (2024). Conversely, at too high a concentration, tablets become too compact, resulting in prolonged disintegration time and decreased dissolution, as reported by Sulistyaningrum *et al*. (2018) and Fegade *et al*. (2023). This pattern is also supported by studies by Rosmayati *et al*. (2023) and Sipatu and Ani (2024), which show that variations in binder concentration significantly affect the balance of tablet physical properties, and is reinforced by the results of Dauda *et al*. (2019) which emphasize the differences in characteristics of natural and modified materials.

Furthermore, the effectiveness of the binder is also influenced by the type of material used, as seen in the use of gelatin by Zilhadia *et al*. (2021) and Nurhabibah *et al*. (2023), and modified starch by Kosasih *et al*. (2025). Natural mukilago, as studied by Tessema *et al*. (2025), also shows good potential as long as its composition is properly optimized. On the other hand, the fast-disintegrating tablet system studied by Sulistriyani *et al*. (2022) and the hydrophilic material developed by Ugoeze *et al*. (2021) show that a more porous tablet structure can accelerate the disintegration process without sacrificing overall quality. Therefore, the optimal formula is not the one with the highest hardness, but

rather the one that is able to balance physical stability, ease of disintegration, and adequate drug release.

CONCLUSION

Based on the results of various studies, it can be concluded that binders have a very important role in determining the physical quality and overall performance of tablets, including hardness, friability, disintegration time, and dissolution profile. Variations in the types of binders, both synthetic and natural, show differences in their ability to form compact and stable tablet structures, which are influenced by the physicochemical properties of each material such as plasticity, adhesion ability, and hydrophilic properties.

Synthetic binders such as PVP and Avicel tend to provide more consistent results in increasing tablet hardness and decreasing friability, while natural binders show wider variation in results depending on the source and processing of the material. Increasing the binder concentration generally increases tablet cohesiveness and hardness and decreases friability, but at too high a concentration, it can cause a decrease in dissolution rate and prolong disintegration time due to reduced porosity and liquid penetration.

The relationship between these parameters indicates that tablets with high hardness tend to have low friability, but do not always provide optimal dissolution profiles and disintegration times. Therefore, a good tablet formulation is not determined by a single parameter, but rather by the balance between mechanical strength and drug release capability. Therefore, the most effective tablet formulation optimization strategy is to use binders at optimum concentrations (usually medium levels), while considering interactions with other components such as disintegrants and manufacturing methods. This approach is necessary to produce tablets that meet quality standards while having optimal pharmaceutical performance.

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