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REVIEW

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Banana-derived excipients: drug Release, performance, and stability

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Abstract: Banana-derived excipients have received increasing attention as potential natural and sustainable alternatives in pharmaceutical formulations. This study reviewed the effectiveness and compatibility of banana-based excipients in comparison to conventional synthetic and natural counterparts. A comprehensive literature review was conducted using the PICOS framework. Data extraction focused on physicochemical characterization, functional performance, and drug release properties of banana-derived excipients across various dosage forms. Findings indicate that banana starch and crude banana powder exhibit promising binding, disintegrant, and mucoadhesive properties. Their performance in pharmaceutical formulations was comparable to that of commonly used excipients such as maize starch, polyvinylpyrrolidone (PVP), and microcrystalline cellulose. Notably, banana-derived excipients demonstrated sustained-release effects and potential to enhance bioavailability. However, the lack of standardization in processing methods and limited stability data underscore the need for further research to ensure reproducibility and regulatory compliance. Despite their advantages, challenges remain in optimizing formulations and understanding long-term interactions with drug compounds. Future research should prioritize in vivo validation and stability assessments to support the broader adoption of banana-based excipients in pharmaceutical applications. This study contributes to the advancing field of sustainable pharmaceutical development by promoting the integration of environmentally friendly excipients into modern drug formulations.

Keywords: banana-derived excipients, pharmaceutical formulations, bioavailability, disintegration, sustainability

Introduction

Exploring banana-derived excipients has gained significant attention due to their potential benefits in pharmaceutical formulations, particularly in enhancing stability and bioavailability. Studies have demonstrated that banana starch, particularly from *Musa paradisiaca*, can function effectively as a filler, binder, and disintegrant in tablet formulations. Its physicochemical properties are comparable to corn starch, meeting established pharmacopeial standards. While initial research has characterized these excipients, a more comprehensive investigation is required to fully understand their interactions with various drug compounds and their long-term stability in formulations [1].

Further research is essential to establish the safety, efficacy, and regulatory compliance of banana-derived excipients, especially for novel formulations such as fast-dissolving tablets [2]. Incorporating banana peel-derived materials into pharmaceutical formulations offers therapeutic benefits and aligns with the industry's shift toward sustainable practices. This innovative approach could set a precedent for developing environmentally friendly pharmaceuticals [2].

Despite their promising pharmaceutical applications, challenges remain in fully realizing the potential of banana-derived excipients. Comprehensive characterization, bioavailability studies, and regulatory compliance require further exploration. Addressing these gaps can enhance the adoption of banana-based materials in drug formulations, contributing to developing more sustainable and effective pharmaceutical products.

Methods

This literature review followed the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) framework. The research question was: How effective and compatible were banana-derived excipients compared to natural and synthetic excipients in pharmaceutical formulations based on physicochemical characterization and drug release profiles? The population included pharmaceutical dosage forms such as tablets, capsules, and

suppositories. As excipients, the intervention was examined using banana-derived materials, including starch, fiber, mucilage, and extracts. Comparisons were made with other natural and synthetic excipients, while the outcomes assessed involved excipient performance (e.g., binding, disintegration, emulsifying, controlled release) and their impact on formulation stability and bioavailability. The study design encompassed experimental studies and previous systematic reviews.

A comprehensive literature search was carried out using Google Scholar, PubMed, and Scopus, covering research articles published between 2013 and 2024. The search query incorporated keywords related to banana-derived excipients, their effectiveness, compatibility, physicochemical characterization, and drug release profiles. This approach ensured the inclusion of relevant studies that provided empirical data on the pharmaceutical applications of banana-based excipients over a broad period.

Data extraction was performed using a large language model, which was instructed to retrieve key information from each study systematically. The extracted data included the type of banana-derived excipient, specifying the exact plant part used (e.g., peel, starch, mucilage), botanical species/variety, extraction method, and physical form (e.g., powder, solution). Pharmaceutical formulation details were documented, including dosage form type, active pharmaceutical ingredient, concentration or percentage of the banana-derived excipient used, comparison excipients (if applicable), and preparation method (e.g., wet granulation). Exact percentages and concentrations were recorded for all tested formulations.

Physicochemical characterization methods were identified, including spectroscopic techniques (e.g., FT-IR, DSC), compatibility studies, and assessments of physicochemical properties. Functional performance as an excipient was also evaluated, focusing on pharmaceutical functions such as binding, suspending, and disintegration. The review examined comparative performance against conventional excipients, quantitative performance metrics such as disintegration time, hardness, and friability, and statistical comparisons where available. This review aimed to provide a comprehensive understanding of the role, effectiveness, and potential of banana-derived excipients in pharmaceutical formulations by systematically analyzing these aspects.

Results

Characteristics of included studies

Various banana derivatives have been investigated as potential pharmaceutical excipients, with banana starch and crude banana powder being the most studied (Table 1). The reviewed studies indicate that banana derivatives exhibit promising binding, disintegrant, and mucoadhesive properties, as well as influencing tablet characteristics and drug release profiles [3]. Compared to conventional excipients such as maize starch, polyvinylpyrrolidone (PVP), and microcrystalline cellulose, banana-derived excipients demonstrate competitive functional properties [4]. These findings highlight the potential of banana and its derivatives as a sustainable and natural source of pharmaceutical excipients. However, further research is necessary to optimize formulations and comprehensively evaluate their pharmaceutical and technological properties [5].

Effect of banana-derived excipients

Evaluating banana-derived excipients as pharmaceutical binders, diluents, or disintegrants revealed diverse binding strengths, stability characteristics, and dissolution profiles (Table 2). The binding strength assessment indicated that two excipients exhibited binding properties comparable to synthetic alternatives, while one excipient demonstrated inferior binding performance relative to a synthetic counterpart [10]. Additionally, one excipient possessed binding strength equivalent to a natural alternative, and another was described as having good binding properties [4]. However, two excipients were not applicable for binding strength analysis, as their primary functions were as diluents or disintegrants rather than binders [12].

Stability assessment revealed a significant gap in data availability, as stability information was absent for six of the seven excipients studied. The only available data reported that one excipient maintained stability for three months, suggesting potential suitability for pharmaceutical formulations with short-term storage requirements [5]. This lack of comprehensive stability data underscores the need for further investigation to establish the long-term viability of these excipients in pharmaceutical applications.

The dissolution profiles of the studied excipients varied considerably. Among the excipients analyzed, one exhibited a release pattern conforming to the Higuchi model, indicative of diffusion-controlled drug release [3]. Another excipient demonstrated a

Table 1. Characteristics of included studies

Banana derivative type	Study type	Traditional excipient comparator	Primary outcome measure	Ref
Banana Peel pectin	In vitro formulation study	Acacia, Polyvinylpyrrolidone (PVP)	Binding properties, tablet characteristics	[3]
Banana starch	In vitro formulation study	Maize starch BP	Disintegrant properties, tablet characteristics	[4]
Banana starch mucilage	In vitro formulation study	Maize starch, Polyvinylpyrrolidone (PVP)	Binding properties, tablet characteristics	[6]
Crude banana powder	In vitro formulation study	Carbopol 934P	Mucoadhesive properties, drug release	[7]
Musa acuminata starch	In vitro formulation study	Maize starch	Diluent properties, tablet characteristics	
Crude banana powder	In vitro formulation study	No mention found	Mucoadhesive properties, drug release	[8]
Banana starch	In vitro formulation study	Corn starch, Papaya starch	Disintegrant properties, tablet characteristics	[9]
Musa paradisiaca stem mucilage	In vitro formulation study	Starch, Microcrystalline cellulose	Binding and disintegrant properties, tablet characteristics	[10]
Banana peel mucilage	In vitro formulation study	Polyvinylpyrrolidone (PVP), Sodium Carboxymethyl-cellulose (CMC)	Binding and suspending properties, formulation characteristics	[5]
Dehydrated banana powder	In vitro formulation study	Croscarmellose sodium, Microcrystalline cellulose, Cross povidone	Disintegrant properties, tablet characteristics	[11]

Table 2. Physical properties and stability

Excipient type	Binding strength	Stability parameters	Dissolution profile	Ref
Banana peel pectin	Comparable to Acacia and Polyvinylpyrrolidone (PVP)	No mention found	Fitted Higuchi model release kinetics	[3]
Banana Starch	Comparable to maize starch and Polyvinylpyrrolidone (PVP)	No mention found	No mention found	[4]
Crude banana powder	Inferior to Carbopol 934P	No mention found	Sustained release effect	[7]
Musa acuminata starch	Not applicable (used as diluent)	No mention found	No mention found	[12]
Musa paradisiaca stem mucilage	Like starch	No mention found	Release-retarding effect at higher concentrations	[10]
Banana peel mucilage	Good binding properties at 10% w/w	No mention found	Decreased drug release rate with increased concentration	[5]
Dehydrated banana powder	Not applicable (used as disintegrant)	Stable for three months	Comparable to synthetic super disintegrants	[11]

sustained-release effect [10], while a different excipient exhibited a release-retarding effect [8]. Additionally, one excipient displayed a decreased release rate with increasing concentration, suggesting its potential use in modified-release formulations [1]. One excipient exhibited a dissolution profile comparable to synthetic super disintegrants, indicating its potential utility in enhancing drug release [4]. However, dissolution profile data was unavailable for two excipients, limiting a comprehensive comparison.

Discussion

The findings of this study underscore the versatility and potential of banana-derived excipients as functional alternatives to conventional pharmaceutical excipients. The comparative analysis across different dosage forms suggests that banana-based materials exhibit competitive performance in multiple roles, including binding, disintegration, and mucoadhesion. Notably, banana peel pectin demonstrated binding properties like Acacia and PVP, while banana starch mucilage showed comparable efficacy to maize starch and PVP in metformin tablets [3][6], suggesting their viability as substitutes for commonly used synthetic binders in tablet formulations. Moreover, the dual functionality of Musa paradisiaca stem mucilage as both a binder and a disintegrant highlights its formulation flexibility, potentially streamlining the excipient composition of pharmaceutical products [10].

In the context of disintegration, banana starch demonstrated performance comparable to maize starch in paracetamol tablets, and dehydrated banana powder exhibited properties like synthetic super disintegrants in ibuprofen tablets [4][2]. These results suggest that banana-derived excipients could enhance tablet disintegration, facilitating faster drug release. However, some variations were noted depending on the formulation and reference excipient used, indicating the need for further optimization and standardization. Additionally, crude banana powder displayed mucoadhesive properties, although its adhesion strength was lower than Carbopol 934P [7]. The reported enhancement of mucoadhesive strength in formulations containing crude banana powder suggests its potential role in improving mucosal retention and drug bioavailability [8].

Despite the promising functional characteristics, current research on banana-derived excipients presents several limitations. Most studies have concentrated on tablet formulations, with limited investigation into other dosage forms such as capsules, transdermal patches, or controlled-release systems. This narrow focus limits the generalizability of the findings and underscores the need for broader exploration across diverse pharmaceutical applications. Moreover, although banana-derived excipients demonstrated favorable performance in comparative studies, their effectiveness varied depending on their specific pharmaceutical function and the reference excipient used. The development and adoption of standardized evaluation protocols are essential to ensure consistency across different formulations and manufacturing conditions.

The economic feasibility of banana-derived excipients is another critical aspect. Although cost-effectiveness was not explicitly quantified in most studies, their natural abundance and ease of extraction suggest potential economic advantages over synthetic counterparts. The local availability of banana-based excipients could reduce reliance on imported pharmaceutical ingredients, thereby lowering production costs and enhancing supply chain resilience, particularly in banana-producing regions [2][12]. Moreover, the multifunctionality of these excipients, particularly their ability to serve as both binders and disintegrants, could further reduce manufacturing complexity and costs [3].

Processing methods significantly influence the functional properties of banana-derived excipients. Extraction techniques such as aqueous extraction, acetone precipitation, and dehydration impact the physicochemical characteristics of the final product [6][10]. Variability in these methods across different studies challenges ensuring reproducibility and standardization. Additionally, factors such as the maturity stage of the banana plant and the specific plant component used (e.g., peel, stem, or starch) affect the composition and performance of the excipients [12]. Establishing standardized processing protocols is essential to optimize their pharmaceutical applications.

While in vitro assessments have demonstrated promising functional properties, direct investigations into the impact of banana-derived excipients on drug bioavailability remain limited. Crude banana powder's mucoadhesive properties suggest potential benefits for enhancing drug absorption, but comprehensive in vivo pharmacokinetic evaluations are needed to validate these effects [8]. Similarly, the sustained-release and release-retarding properties observed in some formulations require further exploration to determine their practical applications in controlled drug delivery [10][8]. Without clinical validation, translating these findings into commercial pharmaceutical products remains uncertain.

Conclusion

Banana-derived excipients exhibit significant potential as natural, sustainable alternatives to

conventional pharmaceutical excipients. Their diverse functionalities, including binding, disintegration, and mucoadhesion, make them promising candidates for various pharmaceutical formulations. However, limitations such as variability in processing methods, limited dosage form applications, and a lack of in vivo validation must be addressed to facilitate their broader adoption. Further research should focus on optimizing formulation parameters, establishing standardized evaluation protocols, and conducting clinical studies to confirm their therapeutic relevance. The translation value of this work lies in its potential to contribute to the development of cost-effective, environmentally sustainable pharmaceutical excipients, particularly in regions with abundant banana cultivation.

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Declaration of interest

None.

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