



Mango seed kernel starch as a pharmaceutical excipient: Extraction, characterization and pharmaceutical applications – A review

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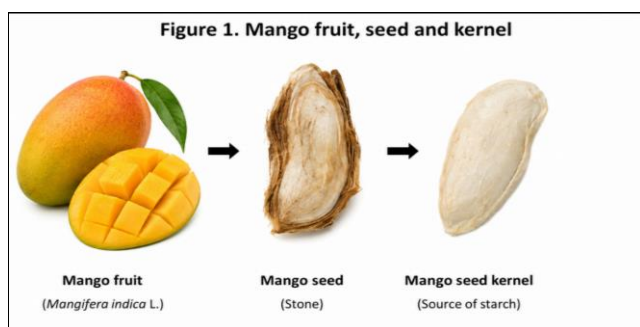
Abstract

Natural polymers have attracted immense consideration in the field of pharmacy due to their biodegradability, biocompatibility, negligible toxicity and economical production. Starch isolated from mango seed kernel has emerged as a promising pharmaceutical excipient because of its physicochemical and functional properties. Mango (*Mangifera indica* L.) is one of the most economically important tropical fruits cultivated worldwide. The fruit is processed into juices, pulp, jams, beverages and other products on a commercial scale resulting in the generation of large amounts of waste including peels and seeds. The kernel present inside the seed constitutes a significant portion of the fruit and is an important source of starch, carbohydrates, proteins, lipids, and other phytoconstituents. In recent years, there has been an emerging interest in utilizing the kernel as a valuable source of starch with diverse pharmaceutical applications. This review compiles the information regarding the physicochemical properties, characterization techniques and pharmaceutical applications of mango seed kernel starch. The review also highlights the advantages and limitations of using starch from mango seed kernel as a pharmaceutical excipient.

Keywords: Mango seed kernel starch, pharmaceutical excipient, natural polymer, extraction, controlled release, nanoparticles, sustainable materials

Introduction

The use of natural excipients in pharmaceutical formulations has witnessed a paradigm shift over the past decade due to an increased awareness about the toxicological effects, environmental impact and high cost of synthetic polymers. Natural polymers offer a wide range of functional properties and are considered to be biodegradable and biocompatible. Starch is one such natural polymer that is extensively used in the pharmaceutical industry for various applications ^[1, 2]



Mango (*Mangifera indica* L.), belonging to the family Anacardiaceae, is one of the most economically important tropical fruits cultivated in India, Asia, Africa and South America. The fruit is consumed fresh and processed into juices, pulp, jams, nectar, pickles and other products on a commercial scale. The processing of mango fruits generates large amounts of waste in the form of peels and seeds. The seed constitutes 10–25% of the fruit and the kernel present inside the seed is an important source of starch, proteins, lipids, carbohydrates and other phytoconstituents. Traditionally, the kernel has been discarded as waste leading to environmental pollution. However, in recent years, there

has been an emerging interest in utilizing this agro-industrial waste as a source of starch with diverse pharmaceutical applications ^[3]. The starch obtained from mango seed kernel has a number of functional properties including swelling capacity, water absorption, compressibility, film-forming ability and biodegradability. These properties make it suitable for various pharmaceutical applications such as binder, disintegrant, diluent, film-forming agent and controlled release polymer. The present review compiles the information regarding the physicochemical properties, characterization techniques and pharmaceutical applications of mango seed kernel starch. The review also highlights the advantages and limitations of using starch from mango seed kernel as a pharmaceutical excipient ^[4].

Mango Seed Kernel: Source and Composition

1. Mango Seed Kernel

Mango (*Mangifera indica* L.), belonging to the family Anacardiaceae, is one of the most economically important tropical fruits cultivated in India, Asia, Africa and South America. The fruit is consumed fresh and processed into juices, pulp, jams, nectar, pickles and other products on a commercial scale. The processing of mango fruits generates large amounts of waste in the form of peels and seeds. The seed constitutes 10–25% of the fruit and the kernel present inside the seed is an important source of starch, proteins, lipids, carbohydrates and other phytoconstituents ^[3].

2. Chemical Composition of Mango Seed Kernel

The chemical composition of mango seed kernel varies depending on the variety of mango, geographical origin, degree of maturity and method of extraction. The kernel

generally consists of starch as the major component along with proteins, fats, crude fibre, ash and moisture.

Table 1: Typical Chemical Composition of Mango Seed Kernel ^[5]

Component	Approximate Content (%)
Starch	55.0 – 70.0
Moisture	8.0 – 12.0
Fat / Lipids	7.0 – 13.0
Protein	5.0 – 9.0
Crude Fibre	2.0 – 4.0
Ash	1.0 – 3.0

Extraction of Mango Seed Kernel Starch

The extraction of starch from mango seed kernel is a vital step that determines the quality and purity of starch. Various methods have been reported for starch extraction from mango seed kernel. The choice of method depends on the desired level of purity and pharmaceutical application ^[6].

1. Materials Required

The following materials are required for starch extraction from mango seed kernel:

1. Fresh mango seeds
2. Distilled water
3. Sodium hydroxide solution (in case of alkaline extraction)
4. Knife or cutter
5. Hot air oven
6. Grinder or pulverizer
7. Muslin cloth or filter paper
8. Beakers and other glassware

2. Extraction Procedure

The following steps are involved in the extraction of starch from mango seed kernel:

Step 1: Collection of Seeds

Fresh mango seeds are collected from the fruit or fruit processing industries.

Step 2: Washing of Seeds

The collected seeds are washed thoroughly with water to remove any

adhering pulp and unwanted materials.

Step 3: Removal of Seed Coat

The hard seed coat was broken to obtain the white kernel.

Step 4: Washing of Kernel

The obtained kernel was washed with water to remove any dirt, pigments and unwanted materials.

Step 5: Drying of Kernel

The kernel was cut into small pieces and dried under shade or in a hot air oven.

Step 6: Grinding of Kernel

The dried kernel was ground into a fine powder and sieved to obtain a uniform particle size.

Step 7: Extraction of Starch

The ground kernel powder was mixed with water and stirred to obtain a uniform suspension. In some methods, dilute sodium hydroxide solution was added to remove proteins and other impurities.

Step 8: Filtration

The mixture was filtered using muslin cloth or filter paper to separate the coarse fibrous material from the starch suspension.

Step 9: Sedimentation

The obtained starch suspension was left undisturbed for a period of time to allow the starch granules to settle at the bottom.

Step 10: Washing of Starch

The starch sediment was washed repeatedly with water to remove any impurities.

Step 11: Drying of Starch

The starch sediment was dried in a hot air oven and ground into a fine powder. The powder was sieved and stored in an airtight container until further use. ^[2]



Importance of Extraction

Proper extraction improves:

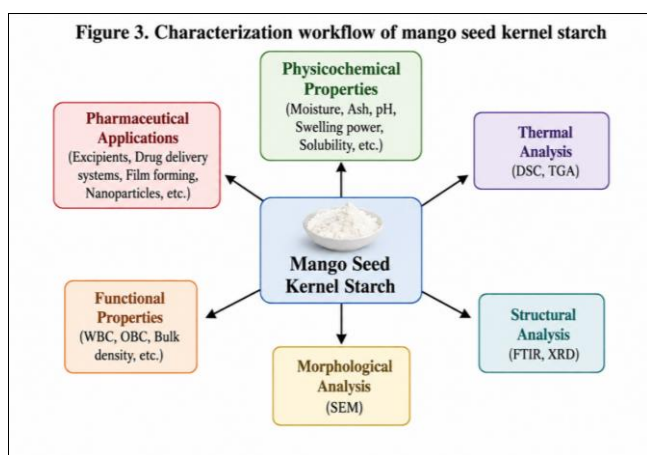
1. Starch yield.
2. Purity of starch.
3. Removal of proteins and lipids.
4. Swelling capacity.
5. Compressibility.

6. Pharmaceutical performance.

A well-extracted starch with improved properties can be used as a binder, disintegrant, diluent, film-forming agent and controlled release polymer in various pharmaceutical formulations ^[7].

Characterization of Mango Seed Kernel Starch

Characterization of mango seed kernel starch is essential in order to determine its chemical composition, surface morphology, crystallinity, and thermal properties. These properties are critical in comprehending the behaviour of starch in pharmaceutical formulations as well as its potential as a natural pharmaceutical excipient. In the current review, the characterization techniques that are primarily considered for mango seed kernel starch include Fourier Transform Infrared Spectroscopy (FTIR), Scanning Electron Microscopy (SEM), X-ray diffraction (XRD), Differential Scanning Calorimetry (DSC), and Thermogravimetric Analysis (TGA). Each technique was evaluated for its relevance in establishing the physicochemical properties of mango seed kernel starch [8].



1. Fourier Transform Infrared Spectroscopy (FTIR)

Fourier Transform Infrared Spectroscopy is a powerful analytical technique used to identify the functional groups present in a compound. FTIR analysis helps in determining the chemical structure of starch by identifying the various functional groups present in it.

Typical functional groups found in starch include

1. Hydroxyl (O-H) groups
2. C-H groups
3. C-O and C-O-C groups
4. Glycosidic linkages

Pharmaceutical Importance

1. Helps in determining the chemical structure of starch.
2. Detects any structural modifications in starch.
3. Evaluates the compatibility of starch with drugs and excipients.
4. Assures the purity of starch.

2. Scanning Electron Microscopy (SEM)

Scanning Electron Microscopy is a powerful analytical technique used to determine the surface morphology of starch granules.

SEM analysis helps in determining

1. Shape of starch granules
2. Surface structure of starch granules
3. Particle size distribution
4. Presence of cracks and defects in the granules
5. Mango seed kernel starch generally consists of oval and spherical shaped granules with a smooth surface.

Pharmaceutical Importance

1. Predicts the flow properties of starch.
2. Determines the tableting properties of starch.
3. Assesses the drug release properties of starch.

3. X-Ray Diffraction (XRD)

X-Ray Diffraction is a powerful analytical technique used to determine the crystalline structure of a compound.

XRD analysis helps in determining

1. The degree of crystallinity of starch
2. The crystal structure of starch
3. The structural organization of starch

Pharmaceutical Importance

1. Helps in determining the structural properties of starch.
2. Predicts the processing behavior of starch.
3. Assesses the gelatinization properties of starch.

4. Differential Scanning Calorimetry (DSC)

Differential Scanning Calorimetry is a powerful analytical technique used to determine the thermal properties of starch.

DSC analysis helps in determining

1. The onset temperature of gelatinization
2. The peak temperature of gelatinization
3. The end temperature of gelatinization
4. The gelatinization enthalpy of starch

Pharmaceutical Importance

1. Helps in determining the thermal stability of starch.
2. Optimizes the processing conditions of starch.
3. Predicts the formulation properties of starch.

5. Thermogravimetric Analysis (TGA)

Thermogravimetric Analysis is a powerful analytical technique used to determine the thermal stability of starch.

TGA analysis helps in determining

1. The weight loss of starch at different temperatures
2. The decomposition temperature of starch
3. The thermal stability of starch
4. The moisture content of starch

Pharmaceutical Importance

1. Helps in determining the thermal stability of starch.
2. Predicts the storage stability of starch.
3. Assesses the applicability of starch in different pharmaceutical processes.

6. Particle Size Analysis

Particle size analysis is a crucial analytical technique that determines the size distribution of starch granules.

The particle size distribution of starch influences various pharmaceutical properties including flowability, compressibility, dissolution rate, etc.

Pharmaceutical Importance

1. Improves the flow properties of starch.
2. Enhances the mixing properties of starch.
3. Ensures uniform tablet formation.
4. Controls the dissolution rate of drugs. [9]

Table 2: Analytical Techniques Used in Starch Characterization

Analytical Technique	Target Parameter	Key Information Obtained
FTIR Spectroscopy	Functional Group Analysis	Identifies functional group linkages (hydroxyl, glycosidic), confirms structural identity, and checks drug-excipient compatibility.
SEM Analysis	Surface Morphology	Determines granule shape (typically oval to spherical), surface topography, smoothness, and presence of structural defects.
X-Ray Diffraction (XRD)	Crystallinity Pattern	Establishes the crystal pattern (A, B, or C type) and quantifies the degree of relative crystallinity.
DSC Thermal Analysis	Phase Transitions	Measures gelatinization onset, peak, end temperatures, and transition enthalpy.
Thermogravimetric Analysis (TGA)	Thermal Stability	Evaluates moisture loss stages, thermal decomposition thresholds, and mass loss profiles under heat.
Particle Size Analysis	Granule Size Distribution	Determines mean granule size and uniformity, which directly govern powder flow and tablet compression.

Physicochemical Properties of Mango Seed Kernel Starch

The physicochemical properties of mango seed kernel starch are pertinent to the physicochemical properties of pharmaceutical formulations as well as their stability, palatability, and therapeutic efficacy. Physicochemical properties that should ideally be determined for any starch material include appearance, moisture content, swelling power, water absorption capacity, solubility, gelatinization temperature, amylose/amylopectin content, density, flow properties, pH, thermal stability, and viscosity. The following discussion highlights the importance of each of these properties in determining the pharmaceutical applicability of mango seed kernel starch ^[10].

1. Appearance

Generally, pure starch material is expected to have a fine white to off-white powder appearance. Therefore, the appearance of a starch sample can be used to infer its purity. In addition, the appearance of a starch sample is an essential criterion for pharmaceutical application since it is useful in determining the quality and/or acceptability of the final drug product.

Pharmaceutical significance

- Preliminary assessment of starch purity
- Evaluation criterion for pharmaceutical application ^[11]

2. Moisture Content

The moisture content of starch is critical in determining its stability. Starch material with relatively high moisture content is more likely to experience destabilization due to microbial activity. However, on the other hand, starch material also needs to have an appropriate level of moisture for its proper functionality. Moisture content is therefore a key indicator of the overall quality of the starch powder.

Pharmaceutical significance

- Moisture content influences physical stability
- Controls microbial proliferation
- Determines storage stability
- Influences shelf-life of starch powder ^[12]

3. Swelling Power

Swelling power describes the ability of starch granules to absorb water and swell upon heating. This property is mainly determined by the molecular structure of the starch, including the relative proportions of amylose and

amylopectin. The ability of starch granules to swell is an essential consideration in the pharmaceutical application of starches. This is primarily because it is a critical predictor of various pharmaceutical phenomena, including tablet disintegration, gel formation, and drug release.

Pharmaceutical significance

- Influences tablet disintegration and drug release
- Determines gel formation capability ^[13]

4. Water Absorption Capacity

Water absorption capacity refers to the ability of starch to absorb water and retain it within its structure. It is an inherent property of starch and, therefore, a crucial predictor of its potential pharmaceutical application. Water absorption capacity is pertinent in determining various aspects of pharmaceutical formulations, including tablet granulation, disintegration, and dissolution.

Pharmaceutical significance

- Determines extent of hydration of the formulation
- Influences granulation process
- Influences tablet disintegration and dissolution
- Predicts hydrophilic matrix potential ^[14]

5. Solubility

Solubility is primarily dictated by the physicochemical properties of a substance. In the case of starch, various factors influence its solubility in water. For instance, the molecular structure of the starch, including the percentage of amylose and amylopectin, as well as the temperature of the solution, play a significant role in dictating how soluble starch is in water.

Pharmaceutical significance

- Influences extent of hydration of the formulation ^[15]

6. Gelatinization Temperature

Gelatinization temperature refers to the temperature range at which starch granules absorb water and undergo structural transition. This property of starch is critical in determining the processing conditions of various pharmaceutical formulations. Gelatinization temperature is typically determined using a DSC analysis.

Pharmaceutical significance

- Influences film formation
- Influences controlled-release mechanism ^[16]

7. Amylose and Amylopectin Content

Amylose and Amylopectin are the two polysaccharides that constitute starch. Amylose is a linear polysaccharide, whereas amylopectin is highly branched. The two components differ significantly in their functionalities and tend to dictate various properties of the starch, including the extent of gelation and swelling power. Amylose is primarily responsible for film formation and viscosity, whereas Amylopectin is mainly involved in the water absorption and swelling capacity of starch.

Pharmaceutical significance

- Amylose determines gelation and film formation
- Amylopectin determines the level of swelling and viscosity ^[17]

8. Bulk Density and Tapped Density

Bulk density refers to the volume of starch powder occupied by a certain mass of the material before tapping. On the other hand, tapped density refers to the volume of starch powder occupied by a certain mass of the material after mechanical tapping. Bulk density and tapped density are crucial in describing the packing properties of starch powders. They can also be used to determine certain other physicochemical properties of starch powders, including flow characteristics and compressibility.

Pharmaceutical significance

- Used to calculate Carr's Compressibility Index
- Used to calculate Hausner Ratio

9. Flow Properties

Flow properties describe the ability of a powder to flow smoothly under the influence of gravity. This characteristic is particularly crucial for pharmaceutical application because it facilitates uniform filling of the dies during tablet compression. Flow properties can be determined using several physicochemical parameters, including Angle of repose, Carr's index, and Hausner ratio.

Pharmaceutical significance

- Plays an essential role in the production of uniform tablets
- Influences tablet weight
- Influences compression process
- Influences die-filling properties ^[18]

10. pH

The pH of a starch sample is significant in determining its compatibility and stability with other pharmaceutical excipients. Ideally, the pH of a drug sample should be within the neutral range in order to reduce the likelihood of interactions.

Pharmaceutical significance

- Predicts the extent of drug-excipient interactions ^[19]

11. Thermal Stability

Thermal stability refers to the ability of starch to withstand the effects of heat. This property is crucial in determining the potential pharmaceutical application of starch. For instance, the ability of starch to tolerate high temperatures during various manufacturing processes is critical in its selection as an excipient for pharmaceutical formulations ^[20].

12. Viscosity

Viscosity can be described as the resistance to deformation in a fluid. In other words, it is a measure of the thickness or consistency of a fluid. Generally, the ability of starch to form thick viscous liquids varies under different conditions. The viscosity profile of a starch sample provides insight into its pharmaceutical application. For instance, a suitable viscosity profile is critical in the production of sustained-release formulations, hydrophilic matrix systems, and other dosage forms.

Pharmaceutical significance

- Influences sustained-release formulation
- Influences hydrophilic matrix systems
- Influences semisolid formulations
- Influences film formation ^[6]

Table 3: Physicochemical Properties and Pharmaceutical Significance ^[21]

Physicochemical Property	Pharmaceutical Significance
Appearance	Preliminary assessment of starch purity
Moisture content	Influences physical stability and shelf life
Swelling power	Influences tablet disintegration and drug release
Water absorption capacity	Influences formulation properties
Solubility	Influences extent of hydration of the formulation
Gelatinization temperature	Determines suitable processing conditions
Amylose/amylopectin ratio	Influences swelling, viscosity and film formation
Bulk and tapped density	Assesses packing properties
Flow properties	Influences tablet manufacturing process
pH	Predicts extent of drug-excipient interactions
Thermal stability	Predicts suitability for processing conditions
Viscosity	Influences gel formation and films

Pharmaceutical Applications of Mango Seed Kernel Starch

1. Introduction

Pharmaceutical excipients are inactive ingredients used as components or diluents in drugs and dosage forms. Natural excipients play an important role in the pharmaceutical field due to their biodegradability, biocompatibility, non-toxicity,

renewability, and cost-effectiveness. Mango seed kernel starch is known for its promising physicochemical, and functional properties, making it a potential natural pharmaceutical excipient. Due to its excellent swelling power, binding capacity, compressibility, water absorption, and film-forming properties, mango seed kernel starch has the ability to be applied as tablets and capsules, controlled-

release dosage forms, nanoparticles, hydrogel, and biodegradable pharmaceutical materials. ^[22]

2. Tablet Binder

A binder is a pharmaceutical excipient capable of binding powder particles together to form tablets during granulation. The binding ability of mango seed kernel starch can be used for tablet production because of its excellent adhesiveness and ability to produce tablets with good mechanical properties during compression.

Advantages of Using Mango Seed Kernel Starch as Tablet Binder

1. Increase tablet hardness.
2. Decrease friability.
3. Produce tablets with good granules.
4. Improve mechanical properties.
5. Increase tablet's integrity ^[23].

3. Disintegrant

A disintegrant is an excipient that facilitates the breakup of tablets in the gastrointestinal tract after administration for faster drug release and absorption in the body; thus, it promotes rapid dissolution of the drug.

Mango seed kernel starch can be used as a natural disintegrant in the production of tablets because of its high swelling power, which allows rapid water imbibition resulting in faster tablet disintegration and drug release.

Advantages of Using Mango Seed Kernel Starch as Disintegrant

1. Rapid water imbibition.
2. Fast tablet disintegration.
3. Fast drug dissolution.
4. Promote drug absorption in the body ^[24].

4. Diluent

A diluent is an excipient that adds volume to the dosage form, particularly when there is a low amount of active pharmaceutical ingredients (API). Due to the good binding properties and compressibility of mango seed kernel starch, it can be used as a filler.

Advantages of Using Mango Seed Kernel Starch as Diluent

1. Achieve good homogeneous mixture of ingredients.
2. Produce tablets with good weight.
3. Improve flow properties of the mixture.
4. Cost-effective ^[25].

5. Controlled Drug Delivery System

Controlled drug delivery system refers to a drug dosage form, which delivers the drug in the body at a predetermined rate to maintain its concentration for a prolonged period after administration. Due to the higher swelling power, and the ability to bind and absorb water, mango seed kernel starch can be employed as a controlled-release pharmaceutical excipient.

Advantages of Using Mango Seed Kernel Starch as Controlled-Release Excipient

1. Achieve prolonged drug action.
2. Reduce the dosing frequency.

3. Increase patient compliance.
4. Maintain effective drug concentration in the body.
5. Reduce side effects caused by frequent dosing ^[26].

6. Film-Former

Mango seed kernel starch has good film-forming properties due to its excellent binding and swelling properties. It produces films after gelatinization. Thus, it can be used as a film-forming agent in the production of pharmaceutical films, oral dissolving films, and biodegradable packaging materials.

Advantages of Using Mango Seed Kernel Starch as Film-Forming Agent

1. It is non-toxic.
2. It is biodegradable.
3. Environmentally friendly.
4. Renewable natural resource ^[27].

7. Nanoparticle

Recent research has shown that starch can be made into spherical-shaped particles called nanoparticles. Nanoparticles could be produced from mango seed kernel starch due to its swelling property, binding ability, and compressibility. Nanoparticles can be used in the pharmaceutical field for drug delivery, transdermal drug delivery, and site-specific drug targeting.

Advantages of Using Mango Seed Kernel Starch in the Production of Nanoparticles

1. Promotes effective drug delivery due to its high surface area.
2. Increase drug loading capacity.
3. Promote controlled drug release.
4. Can be used as an excipient for transdermal drug delivery ^[22].

8. Hydrogel

Hydrogel is a hydrophilic three-dimensional network of hydrophilic polymers capable of imbibing large volumes of water. Mango seed kernel starch can be used for the preparation of hydrogel.

Advantages of Using Mango Seed Kernel Starch in the Production of Hydrogel

1. High water retention capacity.
2. Suitable for wound dressing application.
3. It is biocompatible.
4. Used in the production of drug delivery systems ^[28].

9. Capsule Formulations

Mango seed kernel starch can also be used as a filler and excipient in the production of hard gelatin capsules and plant-based capsules.

Advantages of Using Mango Seed Kernel Starch as Capsule Excipient

1. It has good flow properties.
2. It enhances good uniformity of the mixture.
3. It increases the potency of the formulation.
4. It improves the quality of the capsule formulation ^[29].

10. Biodegradable Materials

Biodegradable materials are becoming more desirable alternatives to conventional non-biodegradable materials

because they do not persist in the environment for long periods after use, causing damage to the ecosystem. Mango seed kernel starch can be used as a biodegradable material.

Applications of Mango Seed Kernel Starch in Biodegradable Materials

1. It can be used in pharmaceutical packaging.
2. It can be used as a drug delivery matrix.
3. It can be used to produce biodegradable films.
4. It can be used in the production of medical devices ^[30].

11. Modified Mango Seed Kernel Starch

Starch is a natural polysaccharide, and its physicochemical properties make it fit for different applications. However, native starch has some limitations that restrict its applications; therefore, it needs to be modified. There are different modification methods, including physical, chemical, and enzymatic modifications. Starch modification improves its physicochemical properties, functional properties, and

pharmaceutical properties.

Advantages of Modified Mango Seed Kernel Starch

1. Improve the compressibility of the starch.
2. Improve the flowability of the starch.
3. Improve the thermal stability of the starch.
4. Enhance the pharmaceutical properties of the starch ^[31].

12. Future Pharmaceutical Applications of Mango Seed Kernel Starch

From the earlier discussion, it can be concluded that mango seed kernel starch has the potential to be used in different pharmaceutical applications, including controlled-release tablets, oro dispersible tablets, and the production of microspheres, nanoparticles, hydrogel, tissue engineering scaffolds, 3D-printed pharmaceutical dosage forms, and bio-based pharmaceutical packaging materials. The following section will discuss the advantages, limitations, and future scope of mango seed kernel starch and compare the findings of different researchers who have worked on the subject ^[32].

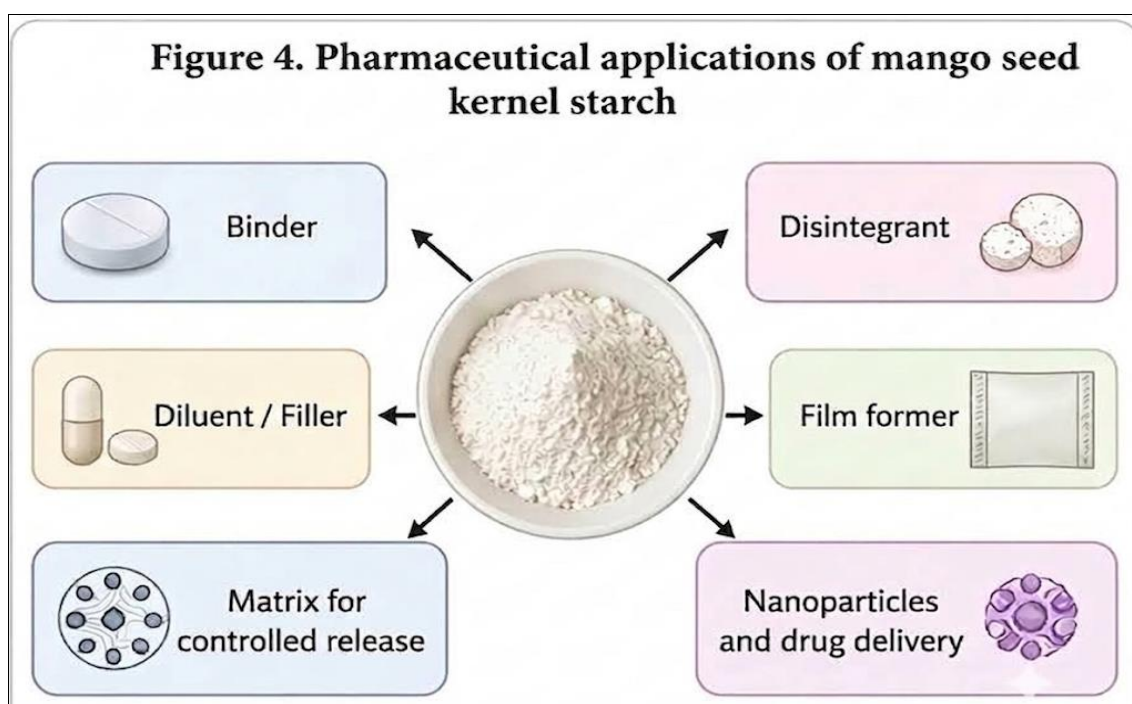


Table 4: Primary Applications in Drug Delivery ^[33]

Application Category	Specific Role / Mechanism	Key Pharmaceutical Advantage
Tablet Binder	Forms strong inter-particular bridges during wet/dry granulation	Enhances compact hardness, reduces friability, and yields mechanically durable tablets.
Tablet Disintegrant	Absorbs fluid rapidly, swells, and generates internal hydraulic disruption pressure	Accelerates tablet breakdown in gastric fluids for rapid API dissolution and absorption.
Tablet Diluent / Filler	Adds required bulk volume to low-dose potent APIs	Ensures uniform drug distribution, excellent blend flow, and dosage consistency.
Controlled-Release Matrix	Forms a hydrated gel barrier that regulates solvent penetration and drug diffusion	Sustains therapeutic blood levels, reduces dosing frequency, and improves patient compliance.
Film-Forming Agent	Produces continuous, clear gel structures upon starch gelatinization	Ideal for oral fast-dissolving films, aqueous tablet coatings, and eco-friendly packaging.
Nanoparticles & Nanocarriers	Serves as a biocompatible polymeric backbone for cross-linked nanospheres	Improves bioavailability, protects sensitive actives, and enables targeted delivery.
Hydrogel Formulations	Creates stable 3D hydrophilic networks capable of holding substantial water	Excellent base for topical drug gels, transdermal patches, and advanced wound dressings.
Capsule Excipient	Functions as a free-flowing bulking powder inside hard capsules	Improves fill consistency and prevents powder stratification during high-speed encapsulation.

Advantages, Limitations, Future Scope and Comparative Analysis of Published Studies

1. Advantages of Mango Seed Kernel Starch

Mango seed kernel starch is a promising natural pharmaceutical excipient because of its physicochemical properties and biodegradable properties. Compared to other synthetic polymers, mango seed kernel starch has a lot of advantages.

1.1 Natural and Renewable Resource

Mango seed kernel starch comes from mango seed scraps that are generated during the extraction of mango juice. Therefore, it is a renewable and natural product. The use of mango seed kernel starch supports value addition and environmental sustainability because it reduces waste generated from the agricultural sector. Additionally, it supports cost reduction in the production of pharmaceutical products because it is a readily available raw material.

1.2 Biodegradable

Like other natural polymers, mango seed kernel starch is biodegradable. Being biodegradable means that it is non-toxic and can decompose naturally without harming the environment. Therefore, it can be used as a substitute for synthetic polymers that have negative effects on the environment.

1.3 Biocompatible Excipient

Because it is a naturally occurring polymer, mango seed kernel starch is biocompatible with other materials. This property makes it useful in the pharmaceutical and biotechnology fields for developing products such as pharmaceutical dosage forms and drug delivery systems.

1.4 Non-Toxic

Mango seed kernel starch is non-toxic and can be used directly without undergoing complicated chemical treatment. Therefore, it can be used as a pharmaceutical excipient in the production of different drug dosage forms.

1.5 Cheap Source of Raw Material

Mango seed kernel starch is a cheap source of raw materials for pharmaceutical, biotechnology, and food industries. This is because most people throw away the mango seeds during the production of mango juice. Therefore, using mango kernel seed starch contributes to a better economy and less waste after mango juice production.

1.6 Good Swelling Capacity

Mango seed kernel starch has a good swelling capacity, which enables it to absorb a lot of moisture. This property is useful in many pharmaceutical applications, including tablet disintegration and the production of sustained-release drugs.

1.7 Excellent Binding Capacity

Mango seed kernel has very good adhesiveness and binding property that can be used in different pharmaceutical applications, for example, producing tablets with good mechanical properties and reducing friability.

1.8 Good Film-Forming Capacity

Mango seed kernel starch can be used to produce biodegradable films that find application in the

pharmaceutical, biotechnology, and packaging industries. The film-forming property is achieved when the starch is mixed with water or other solvents and heated.

1.9 Controlled-Release Property

The controlled-release property of mango seed kernel starch can be utilized in the production of sustained-release dosage forms of drugs. This is achieved by mixing starch with other binding agents to produce hydrogels.

1.10 Wide Pharmaceutical Applications

The physicochemical properties of mango seed kernel starch open it up to various pharmaceutical applications. Some of the pharmaceutical applications of mango seed kernel starch include:

1. Tablet binder
2. Tablet disintegrant
3. Tablet diluent
4. Film former
5. Controlled-release matrix
6. Nanoparticle fabrication

2. Limitations of Mango Seed Kernel Starch

Although mango seed kernel starch has several advantages, it also has some shortcomings that make it difficult to be used in some pharmaceutical applications. The limitations of using mango seed kernel starch include:

2.1 Poor Consistency

The physicochemical properties of mango kernel seed starch depend on the following factors:

- Variety of mangoes
- Environmental factors
- Maturity of the fruit

This means that there are many types of mango seed kernel starch due to differences in their sources.

2.2 Poor Moisture Resistance

Mango seed kernel starch has poor moisture resistance, which limits its industrial application, especially in the pharmaceutical industry. Therefore, moisture affects the stability of any pharmaceutical preparation that contains mango seed kernel starch. This problem is mainly caused by the fact that the starch has a hydrophilic nature and has a high tendency to absorb atmospheric moisture.

2.3 Low Mechanical Strength

Compared to synthetic polymers, native mango seed kernel starch has low mechanical properties. Due to this limitation, mango seed kernel starch is only suitable for limited pharmaceutical applications.

2.4 Prone to Microbial Attack

Mango seed kernel starch is a natural polymer and, therefore, is prone to microbial infection if it is not dried and stored properly. In addition, moisture accelerates microbial attack and degrades the starch.

2.5 Modification of Starch is Required

Some pharmaceutical applications require modified starch rather than native starch. However, native mango seed kernel starch cannot be used directly for all pharmaceutical

applications. For instance, modification of the starch is needed to increase its tensile strength.

2.6 No Industry-Scale Production

Although mango seed kernel starch has a lot of potential, it is currently not produced in large scale because of the lack of proper industrial processing.

Table 5: Advantages and Limitations of Mango Seed Kernel Starch [34]

Advantages	limitations
Natural polymer	Poor consistency
Biodegradable	Poor moisture resistance
Biocompatible	Low mechanical strength
Non-toxic	Prone to microbial attack
Cost-effective	Modification is needed
Renewable resource	No industry-scale production



3. Future Scope of Mango Seed Kernel Starch

There is a growing need for eco-friendly pharmaceutical excipients with biodegradable properties. The scope of the mango seed kernel is expanding due to its physicochemical properties, making it suitable for various industrial applications. Future pharmaceutical applications of mango seed kernel starch can include:

- 1. Fabrication of new drug delivery systems.
- 2. Production of starch nanoparticles for drug delivery.
- 3. Application of hydrogel in different pharmaceutical dosage forms.
- 4. Tissue engineering.
- 5. Production of biodegradable packaging materials.
- 6. 3D-printing pharmaceutical dosage forms.
- 7. Modification of mango starch to improve its functional properties.
- 8. Industrial-scale production of mango seed kernel starch.
- 9. Clinical trials.
- 10. Commercialization of different pharmaceutical dosage forms made of mango seed kernel starch [35].

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