Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 13-24 | ISSN:2251-6727

The Practice of Employing the Water Steeping Method to Extract Native Starch from Potatoes

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(Received: 07 January 2024 Revised: 12 February 2024 Accepted: 06 March 2024)

KEYWORDS

Potato starch; cellulose; fiber; hydro cyclone; antioxidant

ABSTRACT:

Many plants manufacture starch, a naturally occurring, renewable, and biodegradable polymer, as a means of storing energy. Starches can be used in a variety of ways due to their diverse structures and functions. Starch's functional characteristics can be altered and improved through a variety of physical, chemical, and enzymatic changes, enabling its application in a range of medicinal contexts. The Food and Drug Administration (FDA) of the United States has authorized certain starches, such as sodium starch glycolate (modified starch by chemical reaction), native starch and pregelatinized starch (a starch that has been physically enhanced), for use as a matrix or as an isolated excipient in drug delivery systems, such as capsules, granules, tablets, suppositories, implants, stents, transdermal, and ophthalmic systems. However, formulators are under pressure to find current excipients that accomplish the required set of functionalities due to the growing number of drug moieties with differing stability and physicochemical properties as well as the development of new drug production techniques and drug delivery systems. Whether used as excipients or as drug delivery systems, native and modified starches are widely used in pharmaceutical and biomedical applications. Recent advancements in pharmaceutical applications highlight the characteristics of potato starch. This paper provides a thorough review of making potato starches.

1. Introduction

Often used as a disintegrant as well as a binder, starch is an excipient in tablets. In Europe and the USA, respectively, potato starch and maize starch are commonly utilized. Less is used of tapioca and wheat starches; the latter two are mostly employed in tropical nations. Some of the natural species found in many tropical countries have been studied because they may be used as a source of starch for medicinal applications. [1]

The two particularly prevalent poisonous glycoalkaloids found in potatoes are solanine and chaconine [2].

Germany manufactured potato starch for the first time close to the close of the seventeenth century. Soil removal and Cleaning on rotating bar screens, cell opening by high-speed raspers, eliminating starch granules and juice from the pulp (cell walls) on rotating conical screens, concentrating the crude starch milk (starch + juice) on hydro cyclones, it is subsequently dried after being cleaned on multistage hydro cyclones in a counter-current with water the starch yield from potatoes is over 96% of their granular starch content. There have been reports of uses for potato starch in the pharmaceutical and biomedical industries as well as in fermentation to produce different kinds of biomolecules.

Table 1. Components of Traditional Wet Potato Pulp –

components	%(w/w) of Wet Pulp	%(w/w) of Dry Matter
Dry matter	**13.0**	**-**
Ashes	**0.5**	**4.0**
Starch	**4.9**	**37.0**
Cellulose	**2.2**	**17.0**
Hemicellulose	**1.8**	**14.0**
Pectin	**2.2**	**17.0**
Fiber(unidentified)	**0.9**	**7.0**
Protein/amino acids	**0.5**	**4.0**

Naturally occurring polymeric polymer compounds like starch could be a source of these multifunctional DC excipients. [3]

For a wide range of end purposes, these starches have been extensively used in the food and beverage, petrochemical, textile, paper, and wood industries. [4]

When creating solid oral dosage forms, the industry uses starch as an excipient, such as capsules and tablets. The quality and source of the starch have determined the concentrations at which they have been utilized as diluent, binder, and/or disintegrant. [5]

1.1 Starch-

Starch, which makes up 60 percent to 80 percent of the material's dry weight, is the plant kingdom's reserve of carbohydrates. It is mostly found in the roots, seeds and tubers of plants. [6]

This polymeric carbohydrate is predominantly composed of α-D-glucosidic linkages connecting anhydro glucose units. It is mostly composed of amylopectin (in a proportion of 70–80%) and amylose (Twenty to thirty percent of the granules of starch). [7]

Starch is deposited in minuscule cells or granules with a diameter of at least 100 mm. [8]

1.2 Nutritional Value-

Sweet potatoes are high in dietary fiber, simple carbs, beta carotene (a substance that is comparable to vitamin A), vitamins C and B6, and starch.

Table 2. Nutritional value of raw sweet potato per 100 grams

Energy	360 KJ (86 Kcal)
Carbohydrate	20.1 g
Starch	12.7 g
Sugars	4.2 g
Dietary fiber	3.0 g
Fat	0.1 g
Protein	1.6 g
Beta carotene	8.5 mg
Thiamine	0.1 mg
Riboflavin	0.1 mg
Niacin	0.6 mg
Pantothenic acid	0.8 mg
Pyridoxine	0.8 mg
Folate	11.0 mg
Ascorbic acid	2.4 mg
Vitamin E	0.3 mg
Calcium	30.0 mg
Iron	0.6 mg
Copper	0.2 mg
Magnesium	25.0 mg
Phosphate	47.0 mg
Potassium	337.0 mg
Sodium	55.0 mg
Zinc	0.3 mg

Since research on animals has demonstrated that they are able to reduce insulin resistance and assist in controlling blood sugar levels, they are thought to be more nutrient-dense than potatoes and can be consumed by diabetics. Its high fiber content in food, which slows down sugar release and digestion, has been linked to this. It has been demonstrated that the plant's leaves and shoots, which are edible, have nutritional levels that are similar to those of pork or beef. [9]

The dry matter of sweet potatoes, according to Bradbury and Holloway (1988), is made up of 70% starch, 10% sugar, 5% protein, 1% fat, 3% ash, 10% fiber. However, because of variations in variety, type of soil, insect and

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frequencies of disease, growing techniques, its composition fluctuates greatly. [10]

1.3 Biochemistry, Source, Morphological Property of Starch

The physical characteristics, biochemistry, and botanical source of starches given the genuine hazards of diseases like genetically modified organisms (GMOs) and bovine spongiform encephalopathy (BSE), transmissible spongiform encephalopathy (TSE), starch extract from animal (glycogen), for this it is not advised for use in pharmaceutical products. [11]

1.4 Distribution and Source of Starch

The main source of stored energy in plants and a biopolymer of carbohydrates is starch. Tubers (yam, potato), cereal grain seeds (rice, corn, sorghum, wheat) legume seeds (beans, peas, lentils), roots (cassava, sweet potato, arrowroot), stem piths (palm, sago) fruits (green bananas, unripe apples, green tomatoes), and leaves (tobacco) all contain them as granules. [12]

In 2004, 60 million metric tonnes were produced in worldwide with corn or maize, making up the majority of the starch; other common sources included wheat, potatoes, tapioca, and rice.

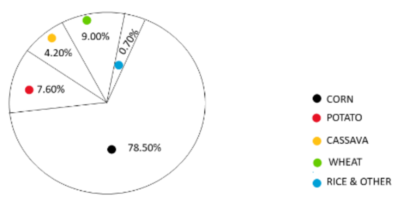

Figure 1 World Wide Starch Production

2. Starch Granules Shape and Size

The size, shape, and dimensions of starch granules vary naturally depending on a variety of factors including the plant source, species, cultivar, interactions with the genetic environment, and growing and harvesting conditions. Potato starch contains big granules (up to 100 µm) compared to the microscopic ones found in oat starches (1.5 - 9.0 µm) and rice.

Potato starch has the widest distribution of sizes, whereas mung bean starch has a rather narrow spread. Certain cereal starches exhibit a bimodal size distribution, including rye, barley, and wheat. According to the Study, the large granules, known as Agranules, are lenticular in form and have a diameter of approximately 20 µm, while the small granules, known as B-granules, a diameter is less than 10 µm, and have a spherical form. [13]

Its swelling functionality is determined by the size distribution. For the most part, starches can be distinguished from one another by their appearance when viewed through a light microscope since their morphological features differ significantly. [14]

Table 3. Characteristics of some starch granules

STARCH SOURCE	DIAMETER RANGE (µm)	AVERAGE DIAMETER (µm)	SHAPE
Corn	2-30	10	Round, polygonal
Waxy corn	3-26	10	Round, polygonal
Wheat	1-45	8	Round, lenticular
Potato	5-100	28	Oval, spherical
Tapioca	4-35	15	Oval, truncated
Mung bean	7-26	NA	Oval, round
Sweet potato	5-35	Na	Polygonal

3. Pharmaceutical Application of Potato Starch

1. Research into biodegradable polymers, both natural and synthetic, has shown a great deal of interest. They are employed in parenteral controlled delivery systems to regulate the rate of drug release. [15]
2. Moreover, medication contained in injectable biodegradable micro- or nanospheres allows for direct delivery of the drug to the site of action. [16]
Additionally, because they shield proteins and peptides from premature inactivation, they have immense potential for protein and peptide delivery. [17]
3. A biodegradable polymer is one of the most prevalent polymers for controlled drug delivery applications.

which has the significant benefit of being cleared from the body when therapeutic chemicals are released. Because of their strong mechanical strength, high oxygen barrier, and favourable moulding and film-forming qualities, a variety of starches and their derivatives have been extensively researched.
[18 19 20 21]

4. Wet binders, diluents, and disintegrants are applications for native starches. They are less advantageous in direct compression, nevertheless, due to their low flow and high lubricant sensitivity. Native starches have undergone a number of chemical, mechanical, and physical changes to enhance their controlled-release and direct compression capabilities. [22]
5. Using starch which is made by potato as an excipient and, using statistical techniques, contrasted its granulating behavior in a lab fluidized bed granulator with that of anhydrous dicalcium phosphate and α-lactose monohydrate. [23]
6. Explored coating a powder combination for interactive medicine that has a prolonged release. The drug particles in the interaction powder mixture were coated on the surface of potato starch and then encapsulated in magnesium stearate to create a preparation with a sustained release. [24]
7. Both pulsed laser deposition utilizing a rotating technique and fluidization of the powder through vibration were used to deposit the indomethacin nanoparticles directly onto the powder which are made by potato as an excipient. [25]
8. Compared to commercially accessible excipients for direct compression, starch acetates were assessed for their impact on physical and tablet qualities as well as the impacts of substituting them. [26]
9. examined the rate at which drugs are released from native starches and acetylated. Their findings demonstrated that the degree of substitution may be used to alter the release profiles and that the acetylation of potato starch might significantly delay medication release. [27]
10. For short-half-life medications, Controlled-release drug delivery systems are being employed more and more to lower peak blood levels and adverse effects, maintain ideal drug concentration, and encourage patient compliance. A steady in vitro drug release rate is needed to keep the medicine at a consistent level in the blood for a long time. The matrix tablet has become the most widely used controlled-release device. [28]
11. Discussed the creation and binding characteristics of potato starch products with a large surface area. [29]
12. It has been demonstrated that starch microparticles work incredibly well for the regulated release of the anti-inflammatory drug meclofenamic acid. [30]
13. Centered on the principles of the injection molding technique for potato starch. In order to determine apparent melt viscosities, a quantitative analysis of the rheological behavior of starch/water melts throughout the refill phase of the injection molding cycle was conducted. Lastly, the drug-delivery characteristics of starch capsules and the mechanical characteristics of molded starch materials were also covered. [31]

4. Other applications

I. Animal feed

- Cattle use silage as a major winter feed source, as it is made by carefully fermenting high moisture content fodder. The main goal of efforts to use potato pulp more extensively was to use it as animal feed. [32]
- Okine et al examined how the inclusion of two bacterial inoculants,R. oryzaea and Lactobacillus rhamnosus, throughout the ensiling process, affected the nutritional value, and alterations in nutrient composition of potato pulp silage. They came to the conclusion that bacterial inoculants or not, potato pulp can ensile well. [33]
- A two-step fermentation process can be used to turn starch made by potato manufacturing waste into single-cell protein (SCP). [34]

II. TECHNICAL APPLICATION

- Tiny pulp fractions are all that are needed for technical uses like making glue. [35]
- Mayer et al reported the physical modification, microbiological characterization, and application of potato pulp. [36]
- Gupta et al have documented the use of potato plant agricultural waste to remove dye pollution from the paper, leather, and textile industries. [37]

III. FUNCTIONAL FOOD

- Abe et al. revealed that ragi tape-fermented potato pulp can be eaten like regular tape products. They used microbial fermentation to transform potato pulp into a pleasant dish, and they contrasted the microflora of tape derived from potato pulp with tape

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ketan, the traditional tape manufactured from glutinous rice. [38]

- ❖ One potential new source of natural antioxidants is potato peels. There are phenolic acids in potato peels. [39]
- ❖ Al-Weshahy examined the antioxidant capabilities and polyphenolic content of potato peel samples cultivated in Ontario, Canada. [40]
- ❖ Potato peel waste presents a promising source of biologically active secondary metabolites called steroidal alkaloids, which include α-solanine, α-chaconine, solanidine, and demissidine. These compounds may operate as precursors to medicines with anti-inflammatory, chemopreventive, and apoptotic effects. [41]b

IV.PAPER INDUSTRY

When producing paper, starch is used to increase the material's strength, smoothness, and printability.

V. BIODEGRADABLE PLASTICS

Starch is utilized as a raw material for producing environmentally friendly and biodegradable plastics.

5. Methods

HOW TO EXTRACT STARCH FROM POTATO

There are various ways to prepare potatoes in order to extract starch. It is not necessary to examine the initial procedures which start as soon as the potatoes arrive and continue through sampling, storing, washing, and grinding. Most circumstances, these steps are roughly equal.

1. Grinding

Breaking the potato's cells to release the starch granules is the aim of this stage. As a result, shredding the potatoes is the first step. It is done in ultra-rasps (Fig 2). Sawblades are used in these drum rasps to rasp potatoes between a perforated plate and the drum. The slurry made of potatoes passes via the sieve plate and gathers in the tank. An antioxidant is added to the potato juice to prevent unwanted coloration. [42]

This antioxidant inhibits the production of reddish-brown melanin by repressing the oxidation of dihydroxyphenylalanine, chlorogenic acid, and tyrosine, which is catalyzed by the potato enzyme polyphenol oxidase. [43]

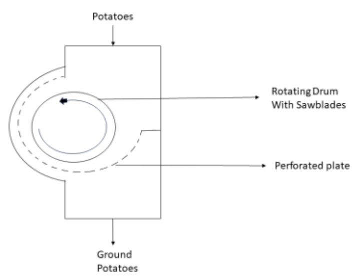

Figure 2: Rasp used for shredding potatoes.

Using a vacuum system to crush the potatoes and eliminate any oxygen is another technique to stop the coloration of the potato juice. Nevertheless, one of the drawbacks of vacuum grinding is that, in order to stop the reaction from happening later in the process, the remaining steps must also be closed. 98% of the granules of starch are released from the cells during grinding, producing an average of 177 kg of potatoes per ton and a UWW of 450 g for every 5050 g of potatoes.

2. Potato Juice Extraction

Here objective is to extract the pulverized potatoes' potato-based liquid, which contains the fully loaded proteins. This is carried out in a continuous centrifuge called a decanter, which is made out of a cylindrical drum with a screw within (Fig. 3). In order to separate the fiber (density ~1100 kg/m3) and starch granules (density ~1600 kg/m3) from the potato-based juice (density ~1000 kg/m3), the drum and screw create around 3000 g.

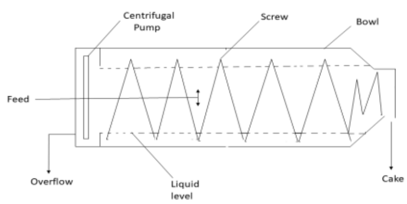

Figure 3 Continuous, decanter-type centrifuge.

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Potato liquid runs across the front of the machine, fiber and solid starch are forced against the drum wall. Potato juice is pumped out using a fixed centrifugal pump installed in the overflow, which is driven by the decanter's torque. The machine's solids are removed via a screw at the back because the screw and the decanter's bowl rotate at slightly different speeds. Two end products are produced by the protein factory. A cake with starch and fibre with approximately 40% of the material is dry and a solids-free potato-based juice overflow. The number of water removal steps and the volume of dilution water utilized determine how well potato juice is removed.

3. Fiber Extraction

This procedure uses sieving to physically separate the particles according to their distribution in size. The diameter of starch granules varies from 1 to 120μm, but the diameter of fiber particles is between 80 and 500μm. The distribution of fiber particles is shown by two Gaussian curves. The larger particles are entire plant cells and more woody fibers; the smaller particles are the walls of the ground cells. A ton of potatoes has 177 kg of starch and 14 kg of fiber, and each 5050 g of potatoes has an underwater weight of 450 g, are indicated by the area under the curves. This phase aims to extract the fiber with a manageable loss of starch from the starch-fiber cake. There can be some little fiber particles in the coarse starch. Centrifugal sieves are used to remove fiber from diluted cake that is extracted from potato juice. This phase aims to extract the fiber with a manageable loss of starch from the starch-fiber cake. There can be some little fiber particles in the coarse starch. Centrifugal sieves are used to remove fiber from diluted cake that is extracted from potato juice. A conical rotating sieve with 125μm openings makes up this kind of sieve (Fig 4).

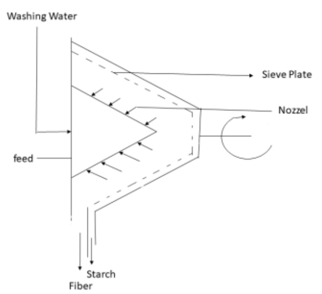

Figure 4 Conical centrifugal sieves.

About 2% of the total starch in the fiber is derived from potato cells that did not break during the grinding process. The volume of water used for washing, and the installed sieve area all affect how successful the sieve is. Typically, 97% of the starch passes through the sieve. This indicates a 2-3% overall loss of starch. There is 1.2% fiber in the starch milk. After being dried to 17% dry matter, the fiber is marketed as feed. A potato starch factory's separation processes are explained using the principle of decreasing efficiency curves. [44]

The classification of solids according to particle size distribution is described by this theory

4. Starch Classification

Following the fiber extraction process, a slurry is produced that contains starch, tiny fiber particles that were left behind, and some of the protein that was not extracted. The classification step's objective is to release the fiber from the starch slurry. separator centrifuge is used for classification of starch (Fig 5).

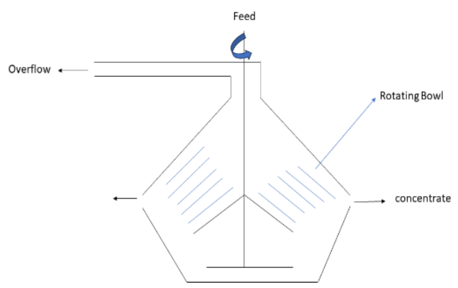

Figure 5 Disk-type, continuous centrifuge.

A continuous disc-type centrifuge is known as a separator centrifuge. Starch concentrates in the separator due to centrifugal force. The area in front of the nozzles is home to the densest starch granules. This concentrate, which has a 40-weight percent starch content, is extracted from the separator in a predetermined quantity (defined by the diameter of the nozzle). The less-dense fiber and smaller starch granules, as well as the soluble ingredients and process water, end up in the overflow.

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5. Starch Refinery

Starch Following classification, the slurry has some soluble and starch that weren't eliminated during the extraction of potato juice.

The soluble protein is extracted by the starch refinery. After diluting the starch with water, the protein is eliminated using a multi-stage, counter-current flow system (hydrocyclones) (Fig 6).
[45]

Images of a single cyclone and the nine-stage counter current starch refinery network are provided. Tangential flow is produced by the cyclone.

Hence, heavier particles—such as starch granules—flow in a top-to-bottom manner toward the hydro cyclone wall.

A slurry of concentrated starch seeps out of the cyclone's base. [46]

The flow direction is reversible in the center of the cyclone, moving from bottom to top. Process water free of starch exits at the cyclone's summit. [47]

AVEBE has created its own hydro cyclones since the majority of hydro cyclone types used in industry lack geometries appropriate for the potato starch sector. [48]

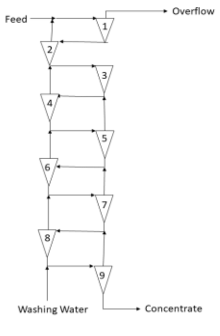

Figure 6: 9-stage starch refinery

These cyclones are better than other starch cyclones because of the increased concentration of potato starch granules at the outlet so fewer washing stages and/or less washing water is required. The starch process schematic diagram shows an optional sieve block. The starch slurry may contain contaminants from the potatoes' place of origin, such as wood, sand, peat, etc.
With particles that are at least 90 µm in size and have densities that are either higher than or equal to those of starch. Thus far, the method has not included a separation stage regarding this kind of substance (the portion having 125 µm diameters)

This dirt component can be separated from the starch by using an optional sieve. Taking off all the dirt and starch is the first step. Recovering as much starch as feasible is the second stage in order to maintain the highest possible output.

6. Sideline Extraction

The goal of sideline extraction is to recover the starch (fine granules) lost during the classification overflow.

Starch and fiber have sufficiently diverse particle sizes to allow sieving to be used for separation. The conical rotating sieves with a mesh size of only 70 µm are the identical ones that were employed for the fibre extraction. After that, The fiber part is then mixed with the fiber from the fiber extraction. The portion of starch that makes up 11% of the total starch is refined in the same manner as the other starch despite still having an abnormally high protein concentration. With 2% lost during grinding and another 2% during the remainder of the operation, the overall starch recovery is approximately 96%.

7. Removal of Water from Starch

This method unit's objective is to extract as much water as possible from the starch. The amount of water that needs to be evaporated in a dryer will decrease In this process, a greater amount of water is extracted mechanically. On revolving vacuum drum filters, the water from the starch refinery concentrate is eliminated. This results in a 40% moisture starch cake.

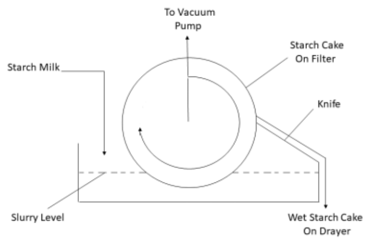

Figure 7 Vacuum Drum Filter

In (fig 7), the filter's schematic diagram is displayed. A tank is present filled with the starch slurry. This tank has a rotating drum that contains a filter cloth. The pressure differential across the fabric is the cause of this. Water is able to travel through the cloth while the starch cakes onto it. As the filter drum rotates, using the knife, the starch cake is removed from it. Using spray nozzles, water is continuously sprayed over the filter to clean it. After the filter's about four hours of operation, After removing the cake, the surface of the filter is cleaned. The wet starch cake is moved to the dryer (either using a screw or a conveyer belt).

8. Starch Drying and Storage

Drying the starch until its moisture content reaches its equilibrium of about 20 percent moisture is the aim of this operation. The dryer is a Pneumatic ring dryer (fig 8).

There are four unique parts to the dryer. The air must be heated to 150°C for the first step. Usually, steam is used in a heat exchanger for a purpose. Hot air is used to dry the starch in a tube that makes up the dryer's second section, or heart. The drying period, or residence time, is around two seconds.

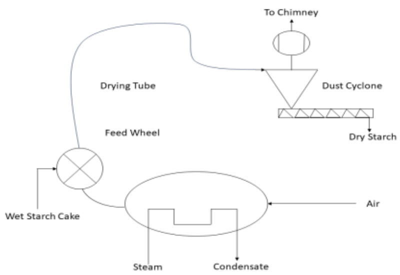

Figure 8 Schematic Diagram of a Pneumatic Starch Dryer

The third step, known as the separation section, is where the air is extracted from the dried starch. Dust cyclones are used for this. The transportation element is the dryer's fourth component. Here, a ventilator provides the kinetic energy needed to move the starch and air through the device. To avoid condensation issues, most of the dried starch is cooled using air before being pneumatically moved to a storage silo. Bulk silos having 30,000 m3 of capacity on average are used to store the starch (Fig 9)

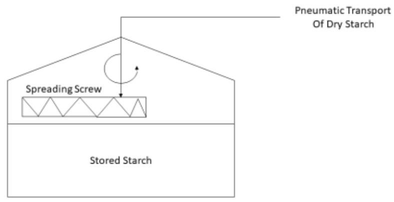

Figure 9 Bulk storage of potato starch

The middle of the silos is full. After that, a revolving screw is used to distribute the starch throughout the surface. throughout the "inter-campaign" phase, the silos are emptied for sale and modification after being filled throughout the campaign. The silos are emptied in the same manner as the filling but in reverse. Thus, the "last in, first out" rule governs how starch is stored.

6. Recent Developments of Starch for Novel Drug Delivery

Because starch is cheap, biocompatible, biodegradable, and nontoxic, its usage in biomedical applications—including innovative drug delivery systems—has advanced significantly. [49]

Furthermore, starch can shield bioactive substances from oxidative or thermal deterioration as well as unfavorable environmental circumstances that are frequently encountered during processing. [50]

These systems have the ability to transport drugs to specific locations within the human body and regulate their release in the small intestine. [51]

These devices are designed to load drugs uniformly and maximize their effects. Because they protect bioactive molecules with very short half-lives, they can boost the bioavailability and maintain the constant and/or prolonged quantities of therapeutic medicines. Furthermore, they enhance patient comfort by avoiding unintended side effects, such as gastrointestinal tract adverse effects like bleeding, peptic ulcers, and gastric erosion, and by optimizing patient therapy by lowering the frequency of drug administration. This is made possible by their ability to deliver high local concentrations. [52]

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JCHR (2024) 14(3), 13-24 | ISSN:2251-6727

These systems must also have the following characteristics:

I. Mechanical strength, as a result of the starch chains' hydrogen bonds, which promote inter-chain interactions;
II. High drug absorption during manufacture, as a result of the various and abundant contact sites that promote both the interactions mentioned above and the interactions between the active ingredients and the starch chains;
III. no unintentional drug release due to the high likelihood of substance absorption from the interface sites; yet, a firm's interaction with the polymeric matrix inhibits or prevents an unwanted release;
IV. simple production since starch may be utilized in a variety of methods due to its versatility.
V. The potential for sterilization.
VI. Builders et al conducted a thorough analysis of the use of starch in drug administration and concluded that due to its inherent qualities, low cost, wide range of applications, and ease of modification, starch will remain a material of significant value in drug delivery. [53]

7. Future Aspects of Potato Starch Processing

New breakthroughs will happen even though the technology used to manufacture potato starch is mature. A more definite starch quality is becoming more and more demanded by the market. The industry that produces starch will shift from being one focused on bulk production to one more focused on commodities. As a result, the potato process will produce distinct starch compounds. For instance, there will be strict guidelines for the particle size distribution or the Brabender or RVA viscosity. The processing of starch which are extracted from potatoes will be enhanced by the application of new or enhanced technologies or methods. The use of enzymes, chemicals, and organic solvents during processing, as well as enhanced methods of separation and classification such as three-phase centrifugal separation and alternative hydrocyclone geometries, are a few examples of these advancements. Increasing the quantity and quality of protein in potatoes, minimizing their susceptibility to disease (or lowering the need for pesticides and herbicides), and optimizing the potato through biotechnological advancements like the amylopectin potato can all help to maximize processes and output. The creation of co-products will be a third significant area. Rather than being handled as waste streams, streams like these will be handled as product streams. The product specification and GMP-like production will receive a lot of attention. Additionally, the recovery of superior co-products (better suited to particular applications) will be looked into. The recovery of citric acid, asparagine, concentrated juice extract from potatoes that has been low-potassium deproteinized, potassium nitrate, food-grade protein, and food-grade fiber are a few examples of this.

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