REVIEW

Pharmaceutical applications of native starch in conventional drug delivery

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Starch is a naturally occurring polymer that is present in many green plants. Its nontoxic and nonirritant properties, as well as low cost, ease of modification, and versatility in use have placed starch in a leading position among polymers used as a pharmaceutical excipient. In many conventional tablets and capsules, starch is used as a diluent, disintegrant, binder, and lubricant. Starch has vital intrinsic properties that have made its pharmaceutical applications possible. It has also been used for a wide range of specialized drug delivery applications, such as delivery of challenging molecules and targeting to specific sites in the body. Although several official native starches with different proprietary identities are available, new sources will continue to evolve with the spate of economic and scientific interest in starch and starch-based products. This review discusses the contemporary trends in the types and application of native starch in conventional drug delivery systems in a world of dynamic drug production technology. It is the authors' opinion that starch will continue to be a material of great value in drug delivery because of its overwhelming intrinsic properties, low cost, versatility in application, and ease of modification.

Keywords:
Native starch / Pharmaceutical applications / Physicochemical properties

1 Introduction

Starch is the principal form of the carbohydrate reserve in green plants and is formed in the cytoplasm of the plant cells in which they occur [1]. Starch in its native form exists as a semi-crystalline molecule called grains or granules. The shape, size, and structure of the granules from each plant are different and are indeed characteristic of that botanical source. Native starch is starch isolated from its botanical source with minimal treatment such that the intrinsic physicochemical properties are maintained after processing [2]. When kept dry, starch is stable in storage for prolonged period [3]. The attraction to the use of starch as a pharmaceutical excipient in various drug delivery technologies and formulations arise primarily due to their physicochemical and functional properties. Both native and modified starches are used as pharmaceutical excipients. Some essential attributes that make native starch attractive for use as a pharmaceutical excipient includes: their white, soft, smooth dryness as well as gelling, and viscosity imparting properties [4]. Also, when they are modified, new attributes are impacted which expand their functions and applications, making them more efficient in both conventional and novel drug delivery systems [5]. Some superior properties of the modified motifs include enhanced flow, disintegration, direct-compression, formation of stable gels in hot and cold water.

When starch is produced in green plants during the process of photosynthesis it is stored in various specialized tissues within the plants such as the root (*Manihot utilissima*), stem/tubers (*Dioscorea* species and *Solanum tuberosum*), and seeds/grains (*Zea mays*, *Triticum aestivum*, and *Oryza sativa*) [6, 7]. Although starch is present in all green plants, the quantity present varies greatly depending

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on botanical source. In many conventional commercial botanical sources the extractable starch content varies from 60 to 80% of the dry weight of the material [7, 8]. The reviews by Moorthy [2002] and Odeku [2013] are highly detailed on the different sources of starch especially those from tropical origin [1, 7]. Sources such as roots and tubers (yams, sweet potato, cassava, cocoyams [taro and tannia], yam bean, Queensland arrowroot, Indian arrowroot, West Indian arrowroot, tacca, ginger), grains and cereals (fonio, millet, sorghum, pigeon pea), and fruits (plantain, ensete, breadfruit, and sago palm) have been documented [1, 7].

Versatility in its uses coupled with its low cost makes starch one of the most extensively used biopolymer in drug delivery technology. Versatility in its uses such as as excipient in drug production coupled with its low cost makes starch one of the most extensively used biopolymer in drug delivery technologies. Starch has extensive intrinsic physical and chemical properties which controls its functional properties and uses. The composition, physicochemical properties, morphology, and pharmaceutical uses of starches from different sources are well documented [7]. This review focuses more closely on the pharmaceutical applications and challenges in the use of native starch as excipient in drug production technology particularly in the formulation of conventional tablets and capsules as well as in certain controlled drug delivery systems.

1.1 Physicochemical properties

1.1.1 Chemical structure

Starch consists of two naturally occurring high molecular weight polymers: amylose and amylopectin both of which consists of a single carbohydrate repeating unit of D-glucose. Fig. 1 shows the chemical structures of amylose and amylopectin polymers. Amylose has a straight chain structure with a few branch points and exhibits α (1→4) linkage [9], while, amylopectin has α (1→6) linkages resulting in a compact, branched structure [9]. Starches in nature usually contain more amylopectin than amylose. Typically, amylose constitutes about one fourth of the starch molecules, while amylopectin makes up three-fourths [10, 11]. In the granule the amylopectin moiety is formed in concentric circles with the amylose dispersed in between and held together by hydrogen bonds [12]. Generally roots and tubers contain more amylopectin than cereals. Waxy starches contain virtually all amylopectin. The differences often observed in certain functional properties of starches, such as crystallinity, viscosity, shear resistance, gelatinization characteristics, solubility, tackiness, paste texture and stability, swelling, and retrogradation are essentially due to differences in the amylose and amylopectin content [9, 13]. This means that in certain applications that are dependent on intrinsic functional properties, starch from one source can not be automatically interchanged with that from another unless empirical correlations in functionality have been validated [3].

1.1.2 Organoleptic properties

Typically, starch is a dry, soft powder that is odorless and bland in taste [3]. The color varies depending on the botanical source, from white to slightly cream; however, starches of cereal origin may have colors that are shades of the seeds from which they are extracted. Sometimes the crude starch may have a slight odor that is characteristic of the botanical source. Though, the intrinsic physicochemical properties of native starches are unaltered, many commercially available

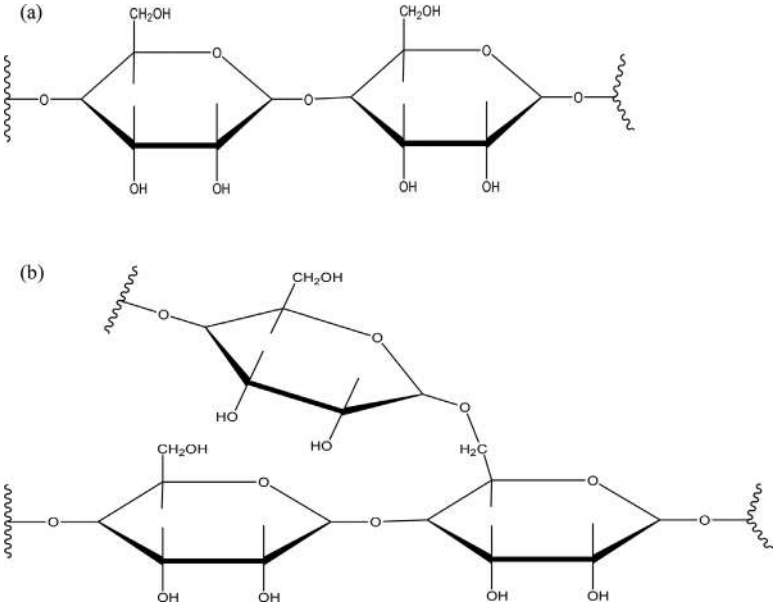

Figure 1. Representative chemical structures of D-glucose units showing α (1→4) linkage of Amylose (a) and α (1→4 and 1→6) linkages of Amylopectin (b).

types are often subjected to certain physical treatment to enhance elegance and modify certain physical properties such as whiteness and moisture content without altering the fundamental intrinsic properties [14].

1.1.3 Morphology

Starch granule morphology is an important parameter used to identify and differentiate starch from different botanical origin. The general presentation, shape and sizes of starch granules from different botanical origin are typical [14]. Based on size description, starch grains can be classified into four categories: large (>25 mm), medium (10–25 mm), small (5–10 mm), and very small (5 mm) [14]. The morphology of many starch grains has been evaluated using the simple light microscope and the scanning electron microscope (SEM). The SEM photomicrographs of some commonly available starches in Nigeria are presented in Fig. 2 [14, 15]. Figure. 2 is a representative SEM photomicrograph of starches obtained from *Z. mays*, *Persea Americana*, and *Cyperus esculentus*. It is important to note that pure starch from a claimed botanical source may contain traces of foreign matter such as tissue fragments (Fig. 2b), it however should not contain any traces of starch (granules) other than from the declared botanical source [3].

1.1.4 Light scattering and iodine reaction

The appearance is such that under polarized light starch has a birefringence appearance. The amylose chain is coiled in the shape of a helix and is responsible for the characteristic purple-black color produced in the presence of iodine ions. The color reaction of iodine dissolved in potassium iodide solution to form the linear triiodide ion complex that enters the helical structure of the amylose moiety is an important identification test for starch. The purple-black color is formed when the iodine ions insert itself into the helical network of the amylose chain making it rigid [16, 17]. The change in color of the starch to either blue or purple will depend on the length of the amylose molecule. Amylopectin is a branching molecule which does not form a helical coil. Thus, the iodine is not able to bind to it.

1.1.5 Crystalline properties

Native starch is described to be semi-crystalline or partly crystalline in nature with varying levels of crystallinity that is associated with the amylopectin and amylose content. The amylose and amylopectin polymers which make up the starch grain define the crystallinity of the unmodified starch. While the amylopectin represent predominantly the crystalline domain of native starch which is characterized by an ordered, tightly packed parallel glucan chains the amylose represent the amorphous region [18]. Starches from different botanical varieties have shown different crystalinity due to variation in their amylose and amylopectin content [19]. Starch from different botanical sources has shown different X-ray diffraction patterns and differential scanning calorimetric thermographs. Four major X-ray diffraction patterns have been described. The pattern for cereal starches (amylose content less than 40%) is described as A. B denotes the pattern for starches from root, tubers, and other sources with high amylose varieties and retrograded starches. C denotes patterns obtained from a mixture of A and B patterns as often obtained from beans and peas while V denotes pattern shown by some high amylose containing starch but more generally by lipid containing gelatinized starch [20, 21]. Starches from different botanical origins are characterized by differences in their thermal transitions as shown in Fig. 3 [15]. Melting transitions are typically characteristic of the crystalline portion which corresponds to the amylopectin moiety.

1.1.6 Solubility

Typically native starch is insoluble in cold water and most organic solvents including acetone, alcohols, and ether. It however becomes soluble in water when the dispersion is heated up to a certain critical temperature called the gelatinization temperature. Gelatinization is a fundamental

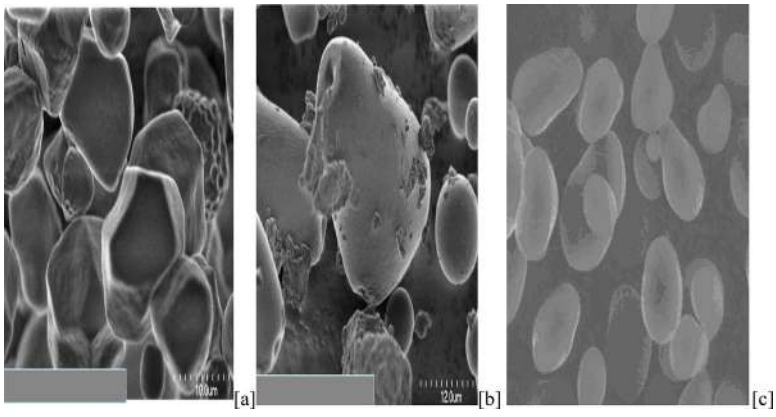

Figure 2. Scanning electron microscopy photomicrographs of some starches obtained from different sources: (a) *Z. mays*, (b) *P. americana*, (c) *C. esculentus*.

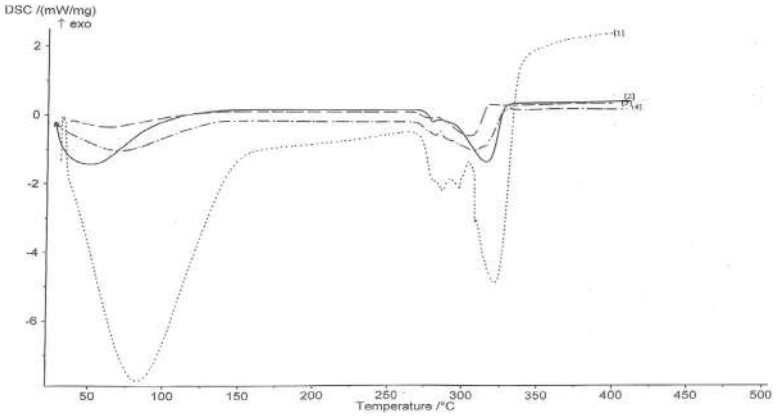

Figure 3. DSC thermographs of starches obtained from: *C. esculentus* (1), *S. tuberosum* (2), *P. americana*, (3), *Z. mays* (4).

property of starch which is characterized by changes in the physical and chemical properties. The process of gelatinization is characterized by an enormous swelling, increased viscosity, translucency, solubility, and loss birefringence [21]. These changes are often due to the breaking of the hydrogen bonds within the starch granules that allows water to enter the granules to make it to swell as the dispersion is heated. As the temperature increases the viscosity of the dispersion also increases until a stable gel is formed. It is also important to note that as the temperature of the dispersion is increased stirring will further increase the viscosity of the dispersion. Gelling is characterized by high viscosity and a total destabilization of the crystalline structure of the granules followed by retrogradation which occurs upon cooling of the gel.

1.1.7 Gelation

Starch gel is formed when starch paste in sufficiently high concentration is cooled. Gelation is said to occur by the formation of a three dimensional network in which swollen granules are bound. Amylose is considered to be primarily responsible for the formation of gels. The more the amylose content, the stringier the gel while the more the amylopectin, the softer and translucent the gel. Among the official starches, potato starch has the highest amylopectin content which is responsible for its higher thickening potential as compared to corn starch which has lower amylopectin content and a stronger gel [22, 23].

1.1.8 Retrogradation

This is an important feature of starch gel which involves a molecular reorganization process characterized by loss of water and partial recovery of the crystalline structure due to the realignment of amylose and amylopectin. The firmness or rigidity of starch gel increases markedly with retrogradation [13]. Retrogradation is induced by such factors as low temperature, high amylose content, and the presence of polar substances, such as salts [24]. On the other hand substances such as surfactants, sugars, lipids, and hydrocolloids hinder retrogradation. Generally the starches with higher amylose content will undergo retrogradation at a more rapid rate than those with higher amylopectin [24–26].

1.2 Pharmaceutical applications

The size of the starch granule also has some important influence on the functional application of some native starches. Rice starch grain is among the smallest of the starch grains measuring 7–9 μm. This has made it desirable for the production of both cosmetic and medicated powders for topical application. This intrinsic smallness in granule size is the reason for its extraordinary soft-touch and large surface area. When applied to the skin, rice starch produces a soft, mattifying effect which also helps minimize the appearance of fine lines, wrinkles, and blemishes. Rice starch is also used as an ingredient for dry shampoo because it absorbs oil in the hair and also adds volume and is easily brushed out. Approximately 1.0 g of rice starch has a surface area of 1.6 m^2 resulting in immense adsorption and absorption characteristics [27, 28]. These properties make rice starch the classical material used for making powders for topical application. Sago starch is an unofficial starch obtained from the sago palms, the physicochemical properties and its potential for use as a body powder and lubricant in certain surgical and diagnostic materials has been investigated [29, 30].

1.3 Starch as a pharmaceutical excipient

Excipients are increasingly being recognized as important components of conventional and novel drug products, providing specific functions in aiding the formulation of optimally elegant, stable, safe, and active drug products [31]. Starch in its native and modified forms has been widely used as pharmaceutical excipient [26]. Starch-based excipients have been shown to offer numerous advantages in drug production in terms of lower cost, safety, and product quality. It has also been evaluated and used as drug carriers in

controlled drug delivery systems [32, 33]. Native starch has traditionally been used for bulk granules, capsules, and tablets production. It has multifunctional uses in the different physical forms serving as binder, disintegrant, diluents, glidant, and lubricant [34, 35].

By using different drug delivery technologies, starches from many botanical sources have been studied extensively as formulation aid with different drug molecules [36, 37]. Apart from the official starch sources namely: rice, wheat, cassava, potato, and maize there are many other sources some of which have potential commercial value [7, 38, 39]. However, an important problem in the use and commercialization of the non-official sources (in Nigeria) are due especially to the difficulty in winning the interest of pharmaceutical manufacturers and other market stake holders to accept the new products. Some of the reason for the negation in the acceptance of these new sources or local starches lies on issues of information and confidence regarding the safety, stability, and general performance of the new starch products as regards their absolute effectiveness in comparison with the already existing types.

As a pharmaceutical excipient starch is employed in different physical forms [26]. When used as a gel in the form of heat swollen aqueous dispersion, it serves as a binder in granules and tablets production. As an ungelatinized dry, soft powder, starch can be employed to perform a series of functions which include disintegrant, diluent, and glidant in conventional tablets or capsules formulations, and as carrier and lubricant in body and face powders and surface carrier for colors and flavors.

1.3.1 Binder properties

Freshly made starch mucilage prepared to gel by heat treatment of the starch dispersion in water has been used extensively as binder in tablets and capsules production using the wet granulation technique [27]. The starch mucilage is incorporated as a gel and functions as a glue to provide the necessary binding force that holds the powder particles together to form the required agglomerates. This also serves to ensure a uniform distribution and controllable release of the active pharmaceutical ingredient (API). When the agglomerates are compressed under optimal load, stable robust tablets are formed [40]. Another important attribute of starch when used as binder is its compatibility with other adjuncts and APIs used in many conventional and novel formulations. The powder mix often comprise of the APIs and other excipients which is granulated to produce uniform distribution of the API and controllable drug release. When starch gel is used as a binder, the granules are produced by wet granulation process usually by massing the powder mix and the starch gel to form a wet mass which is then screened through sieves of appropriate mesh size (1000–1700 μm), depending on the range of the granule size desired [34]. The agglomerates are then dried in a hot air oven at a temperature of between 40 and 60°C for 1–6 h depending on the nature of the API or other excipients or desired formulation type [41–43]. The major attributes of wet granulation using native starch as binder include enhanced powder density and flow, homogeneity of the ingredients, enhanced compaction, optimal drug release, reduced dust during production and desirable tablets, and granule appearance [44, 45]. Native starch gel is incorporated at concentrations of 3–20% w/w of the granule or tablet weight. Typical concentration is usually 5–10% w/w, depending on the starch type [26]. The optimal quantity of the gel required to produce robust granules or tablets is predetermined by optimization studies using any or combinations of such parameters as granule flow, tablet friability and hardness, disintegration time, and dissolution rate [26]. When used appropriately within the precise optimal concentrations for granule formulation it will add sufficient cohesion to the powder mix to produce granules of desirable and optimal physico-mechanical properties that can be packed into sachets, capsule shells or compressed into tablets. Among the official starches, corn starch is the most frequently used in conventional granulation and tablet production technology, however various studies indicate that other starches from non-conventional sources have also shown potential as binder and so could be substituted for corn starch [46, 47].

1.3.2 Disintegrant properties

A disintegrant is an excipient added to a drug mix intended to be formulated into oral tablets or capsules to facilitate the breakup of the tablets or hard shell capsules into smaller particles to promote the rapid release and subsequent absorption of the active drug [48]. Native starch is a classical disintegrant and remain the popular disintegrant used in many conventional tablets and capsules of generic and branded drug products [49]. Maize and potato starches are the most commonly used starch types for this purpose. However, empirical evaluations of starches from other botanical sources has also shown potential as effective disintegrant in oral rapid release tablets and capsules [49, 50]. The various excipients used as disintegrant in conventional rapid release tablets and capsules have different mechanisms of action [26, 51]. However, the mechanisms established for the disintegration ability of native starch are wicking and restoration of deformed starch particles on contact with aqueous fluid. When starch compact wick up water, the hydrogen bonds formed during compaction become disrupted, a phenomena which is further enhanced by the elastic deformation property of starch and the compact loosen-up and disintegrate [51, 52]. The optimal conditions required for the activity of starch as a disintegrant are usually: sufficient quantity of starch in the agglomerates, low compression pressure, and the presence of water [41].

Generally, a good disintegrant must be effective at low concentrations to avoid or reduce its influence on the other properties of the tablet such as hardness, friability, and compaction ability. The properties of the API and other adjuncts are also influential in the efficiency of starch as a disintegrant. As a disintegrant, native starch is employed within the range of 3–25% w/w of the granules' or tablets' weight, a typical concentration is 15% w/w [26]. During granule formulations, optimal disintegrant activity is obtained when half of the starch is included in the granulation mixture as endo-disintegrant while the other half is incorporated directly to the dried granules as exo-disintegrant [53]. The optimum amount of starch that will be used is often determined by optimization studies. When the amount of starch is below the optimum concentration there will be insufficient channels for capillary action thus, ingress of water will be hampered. Also, when the amount of starch is in excess, soft tablets with high friability and tendency to cap will result [53]. These constitute a major drawback in the use of native starch as a disintegrant, thus the drive to develop motifs with enhanced disintegration and compaction abilities.

1.3.3 Diluent properties

In order to achieve effective handling and weight uniformity during manufacture, tablets should not be less than 50 mg in weight and 3 mm in diameter. Thus, to achieve and facilitate effective handling and mixing of especially potent, low dose APIs, diluents are added and become an integral part of the formula. Diluents which are also called fillers are excipients that are added primarily to low dose conventional formulations such as tablets, capsules, and granules to increase weight, facilitate mixing, and improve content uniformity [54]. They are usually incorporated in the range of 5–80% w/w. Sometimes when diluents are added in large quantities they may influence the properties of the product such as the drug release, granule cohesion, flow, and compaction properties [3, 55]. Native starches constitute a class of natural diluents [53, 56]. They have been used for the preparation of standardized triturates of colorants and potent drugs, and to facilitate mixing and handling. Native starches are an insoluble diluent and possess certain desirable intrinsic properties such as absence of risky interactions with most common APIs and excipients, absence of physiological and pharmacological activities as well as consistent physicochemical, and functional properties. When used in high concentration starch will enhance the breakup and interaction with water without interfering with the intrinsic solubility of the API in the medium. On the other hand, its poor compaction ability does not make it a popular choice when direct compression operation is to be considered, this is typically because of its low plasticity, high moisture sensitivity and its tendency to stick to the punches and dies, capping, and low tensile strength [57]. However, compaction-ability and flow can be improved by the wet granulation of the powder mix [58]. Though, native starch is inexpensive, its use as a diluent will depend on such factors as the relative concentration, formulation technique and the properties of the APIs, and other excipients that will be used [34].

1.3.4 Glidant properties

Glidants are excipients that reduce inter-particulate friction, resulting in improved flow of granules and powders. These are nevertheless an important class of excipients considering the weight accuracy and uniformity required by the pharmacopeias, it thus becomes evident that controlling the flow of powders is of utmost importance. During the production of bulk powders, tablets, and capsules, efficient glidants are required to enhance the flow of granules through the feed mechanisms such as from the hopper and, ultimately, as the case may be, into the packaging chamber, tablet die, or capsule shell fill chamber. Starch is one of the glidants that can be used in conventional tablets and capsules manufacture, and is incorporated at a concentration of 2–10% w/w [59]. It is typically a hydrophilic glidant [60, 61]. Maize starch BP [48] has been used as a glidant in tablets and capsules production, other starch types such as cassava [62, 63], yam [64], fonio [65] have also been investigated as potential glidants in tablets production. The glidant properties of native starch in pharmaceutical granules and powders can be evaluated using such parameters as flow rate, flow factor, and angle of repose [65]. An important parameter that controls the glidant efficiency of potential materials is the particle size: The smaller the particle size the more efficient their glidant properties [66, 67].

1.3.5 Lubricant properties

Lubricants are excipients that are added usually in small quantities to powders and granules during tablets and capsules production. There are three functional roles identified with lubricants which are: decreasing the friction at the interface between a tablet's surface and the die wall during ejection by interposing at intermediate layer between the particle constituents of the tablets and the die wall during ejection, reduction in the wear on punches and dies and prevention of the sticking of the tablets to the face of the punch as well as the granules, and powder mix sticking to the dosators and tamping pins of capsule filling machines [68]. The true classical lubricant fulfils these three roles sufficiently. However, the mechanism of the lubricant property of starch is derived by glidant and anti-adherent processes. The dry starch powder is added at concentrations of 2–10% of the weight of the granules or powder mix [59].

Maize starch BP has been used for this purpose [69, 70]. In this dual mechanism, the starch powder will enhance flow, prevent the tablets or granules from sticking to the punches and die walls. For starch to be used as a lubricant, the physicochemical properties of the APIs and other excipients in the formula have to be considered appropriately. When starch is used as a lubricant in tablets and capsule production, the optimum concentrations is obtained by enough trials as starch may also adversely affect the flow and compaction of the powder mix.

1.3.6 Advanced drug delivery

Starch has been investigated as a conventional excipient and special carrier for various molecules in novel drug delivery systems. Variants of native maize starch has been evaluated as an effective film coat for tablets and has also shown potential to retard dissolution and confer controlled release activity [71, 72]. Nanoparticles and matrix systems to deliver drugs to specific sites has also been fabricated with starch [73–74]. Drug delivery to the lungs via the nasal pathway and other specific sites such as to cancer cells and colons has also been evaluated [7]. The objective of using starch-based nanoparticles as a ligand to target cancer cells was aimed potentially to reduce the dose of the toxic anticancer molecules while maintaining its therapeutic effect. Starch nanoparticles have been fabricated by carboxylation and oxidation of the granules [75]. Assam Bora rice starch has been evaluated as a drug carrier for bioadhesive and matrix system to controlled drug delivery to the colon [73, 74].

1.4 Drawbacks of the use of native starch in drug delivery

Despite the functional versatility of native starch, certain properties make it less efficient and dependable as a multifunctional pharmaceutical excipient in conventional and innovative formulations. The intrinsic moisture content and absorption properties are among the important factors that will provide basic information and basis for selecting excipients for a particular formulation. This is because; the moisture content will affect such important properties as the flow, compaction, and tensile strength of granules and tablets [76]. The moisture content of starch is dependent on the relative humidity (RH) of the atmosphere or its storage environment and it increases with increased moisture sorption as the RH of the environment increases [77]. The moisture sorption of starch powder occurs in different stages. It starts with water binding tightly to the anhydrous glucose units throughout the starch grains until 1:1 water: anhydrous glucose stoichiometry is achieved. As more water is absorbed, it becomes less tightly bound and at a stoichiometry of 1:2 (water: anhydrous glucose) the excess water exhibits the properties of bulk water [78]. Generally, water absorbed within the starch particles influences the flow and compaction properties of starch.

Granules' flowability has been shown to fall sharply at 60% RH and stops completely at 70% RH [79]. The adverse effect of high moisture content on the flow of granules and powders may cause serious weight variations during packaging of granules into sachets, production of tablets and capsules especially when automated production systems are employed. Furthermore, processes such as mixing and transfer as well as the stability of moisture sensitive compounds can be undermined [37, 80]. At high RHs, starch has been shown to cake, though this can be suppressed by adding 0.25–0.5% magnesium oxide to the starch [77, 79]. Moisture has a strong influence on the compaction properties of starch. Maximum tablets strength is obtained at equilibrium moisture content of about 10% which corresponds to water and anhydrous glucose stoichiometry of 1:1 and 1:2 which is obtained when stored at RH of 60–70%. Moisture content level below 1:1 stoichiometry will reduce the compactibility of starch and the presence of bulk water will decrease the formation of bonds between starch particles, probably due to the presence of water film between the particles [57]. Moisture content control is important in granules and powders especially when starch is used as diluent or in high concentrations [78].

Though native starch is known to undergo plastic deformation when compressed under pressure to form hard compacts, it is also known to undergo high elastic recovery which results in soft compacts. The tendency of starch to undergo pure plastic deformation is dependent on certain factors which includes moisture content, particle size and shape distributions. These are often responsible to the variation in the compaction characteristic of starches from different botanical sources. In different studies, corn and potato starches have been shown to have better compaction ability than wheat starch while in another study rice starch has a better compaction than corn starch [81]. The flowability of starch is also critically affected by moisture content, particle shape, and size distributions [80]. Rice starch has poor flow due to its small particle sizes which is also the reason for its minimal lubricant sensitivity. Spherically agglomerated rice starch has been developed by spray-drying aqueous dispersions of the starch. This process was found to improve its fluidity and compaction ability. The spray-dried rice starch is currently marketed in Thailand as Eratab® and in The Netherlands as Primotab ET® [33]. Native maize and potato starches have comparatively better flow but its major flaw is its high lubricant sensitivity which results in the formation of lubricant film over the particles during mixing [56]. Generally, poor flow, high lubricant, and moisture sensitivities make native starches unsuitable for direct compression operations [57].

2 Conclusions

Native starches are safe biopolymer that has several uses as pharmaceutical excipient. They are derived from different botanical sources and processed to meet pharmaceutical grade. Starch is widely used in the production of especially oral solid dosage forms such as bulk granules, tablets, and capsules as well as cosmetic and medicated powders. Native starch is employed in such conventional dosage forms as binder, disintegrant, diluents, glidant, and lubricants. Generally, starch offers formulators a favorable option of using a safe, cheap, natural, biocompatible, biodegradable, and multifunctional material to fulfill their needs for an efficient excipient for effective drug delivery. Though, some of its intrinsic physicochemical properties make it less efficient as a multifunctional pharmaceutical excipient. A large library of modified forms currently being developed will be the subject of future reviews. Native starch will however, continue to function as a versatile polymer in the pharmaceutical sector as new commercially viable sources of native starch as well as novel applications and modification products continue to emerge with the spate of attention and research into this material.

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