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Alternative natural sources for commercialised starches as pharmaceutical excipients; Physicochemical properties and applications

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Starch is utilised in manufacturing tablets and capsules as a diluent, binder, and disintegrant, dependent on the formulation requirements. Starch is a prominent pharmaceutical excipient due to its non-toxic, non-irritant characteristics, low cost, ease of modification, availability, and versatility in use. Recent findings report that certain commercial starches have the potential to cause allergies, poor compressibility and poor mechanical qualities, together with high importation costs. Different novel starches have been investigated from sources, especially those of tropical origin, such as tubers (sweet potato and cassava) and cereals (rice and sorghum) for physicochemical properties to explore safe and effective excipients. With the improved properties, modified starches such as pregelatinised and acid-treated starches have been developed physically and chemically as multifunctional excipients such as coating agents, super disintegrants, and controlled-release polymers. Comparing the reviewed data with pharmacopeial specifications, the review highlighted pregelatinised starch and acid-modified millet would be beneficial alternatives to commercial starches with their improved stability, solubility, biocompatibility and cost-effectiveness. Hence, the current review attempts to emphasise the physicochemical properties such as pH, bulk and tapped densities, angle of repose of native and modified starches and their uses as binders, disintegrants and diluents in the pharmaceutical industry.

Keywords: Binder, Disintegrant, Modified starches, Pharmaceutical excipient, Physicochemical properties, Plant starches

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Introduction

The utilisation of different types of starches is increasing worldwide due to their natural occurrence and wide spread distribution. Starch is produced by many plants as an eco-friendly, biocompatible and biodegradable natural polymer and it is also the source of stored energy for plants[1]. Manufacturers attempt to exploit new excipients that have desirable functionalities for the development of new drug delivery systems and drug manufacturing processes. The Food and Drug Administration (FDA) has certified certain starches, such as native starches, chemically modified starches, such as sodium starch glycolate, and physically modified starch, such as pregelatinised starch. These FDA-certified starches are currently used as a single excipient or as a matrix for drug delivery systems in different dosage forms such as tablets, capsules, modified release and transdermal systems[2].

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The particular features of starches are inherently inappropriate for certain applications and, therefore, must be modified to enhance their favourable physicochemical characteristics such as solubility, swelling ability, compressibility and flowability and/or to minimise their imperfections. Conventional sources of starch include cereal crops, legume seeds, tuber crops, and some root tubers, which are used in large amounts in the field of pharmacy[3]. Having high starch content has made them potential sources of commercial starches used in the industry. The growing demand for natural excipients and oral solid dosage forms is expected to propel the worldwide pharmaceutical starch market to substantial growth. It has been anticipated that between 88.1 and 97.7 million tonnes of starch would be produced worldwide in 2020. 75% of this total is derived from maize, with potatoes accounting for 14%, wheat for 7%, and cassava for 14%[4]. Hence, pharmaceutical companies globally are prioritizing starches from sustainable crops as mentioned above to minimize environmental impact.

In Sri Lanka, there are small-scale producers involved in starch production often focusing on cassava or manioc starch. However, information on specific starch manufacturers in Sri Lanka might be limited or not widely publicized. Remarkably, countries such as Sri Lanka and Nigeria import almost all of the pharmaceutical grade starch from overseas creating an unhealthy situation for the economy and the pharmaceutical sector[5]. The market for pharmaceutical excipients is greatly influenced by India, which is one of the biggest manufacturers of maize, cassava, rice and sorghum starches[6].

According to records in the literature, crop losses due to pests and diseases for several of these crops are between 26 and 36 per cent[7]. Therefore, processing these crops into cost-effective and beneficial starches could be the best solution to reduce the annual loss of these crops and cut down the importation cost of commercial starches. Nowadays, starch serves as a binder in granules and tablets production and in un-gelatinised dry form, starch can be employed as a disintegrant and diluent in tablets and capsules formulations and as carrier and lubricant in body and face, powders considering their suitable structural and functional properties, renewability, cost-effectiveness, biocompatibility, biodegradability, safe and non-toxicity[8,9].

Alternative starch sources such as lesser-known tubers, cereals, seeds, and fruits remain underexplored. These could offer unique physicochemical properties suitable for specialized pharmaceutical applications. Moreover, studies often analyse physicochemical and structural properties of different types of starches, but there is a lack of systematic comparison between starches from alternative sources and commercial benchmarks. Lack of comprehensive benchmarking studies makes it difficult to identify alternative starches that can replace or outperform commercial starches. Alternative starches sourced from underutilized plants may offer cost-effective excipient options, particularly for developing nations where access to affordable pharmaceutical raw materials is critical. Hence it is important to perform a systematic, head-to-head comparison of alternative and conventional starches under pharmaceutical formulation conditions.

Therefore, this paper aims to provide a general synopsis of the physicochemical properties of native and modified starches and their applications in a pharmaceutical context by opening a pathway to alternative starch sources that could lower production costs and enable pharmaceutical companies to produce more accessible and affordable pharmaceuticals.

Materials and Methods

All published literature on plant starches and modified starches of tuber crops and cereals were systematically reviewed. Several keywords (plant starches, modified starches, pharmaceutical excipient, and physicochemical properties, tuber crops, and cereals, aqueous and alkaline extraction) were searched for in English databases, including Google, Google Scholar, PubMed, Science Direct, Springer, and Research Gate to retrieve the information found in studies pertaining to our title. The literature published from 2018 to 2024 was reviewed. References are relevant to tuber crops such as sweet potato, cassava, yams and taro yams and cereals such as rice, pearl millet and sorghum, which are easily accessible, available and contain over 50% starch, were mainly reviewed.

Papers published in English from 2018-2024 that examined the physicochemical properties: pH, true density, bulk density, tapped density, particle size, angle of repose, Hausner's ratio, Carr's index, solubility, swelling capacity and the applications of starches as pharmaceutical excipients were included. Duplicate and non-English articles were excluded. Considering inclusion and exclusion criteria, about 50 papers were found and analysed. The physicochemical properties of these starches were evaluated compared to the pharmacopeial specifications given in the Handbook of Pharmaceutical Excipients.

Chemical nature and physicochemical properties of starch

Starch is a polysaccharide composed of two polymers: amylose and amylopectin[10]. Pure starch is a white, tasteless powder with no order that is insoluble in cold water or alcohol[11]. Additionally, the shape, size, structure, and chemical composition of starch granules can differ based on the origin of the starch[9]. Amylose, which makes up 20–25% of typical starch, is a linear molecule in which the glucose units are joined by α [1→ 4] glucosidic linkage. Amylopectin is the chief constituent of starch, and it constitutes between 75-80% of normal starch. The molecule amylopectin is extensively branched and made up of shorter chains of α [1→ 4] D-glucose residue linked by α [1→ 6] D-glucosidic linkage as given in Fig. 1[10, 11].

The phosphate content, granule size distribution, length of de-branched amylopectin chains, and amylose to amylopectin ratio are examples of structural and molecular characteristics that affect the physicochemical characteristics of starch granules such as particle size, morphology, crystal structure, compressibility, flowability, swelling and solubility characteristics[12]. Compressibility and flowability are key parameters considered during the manufacturing of tablets and capsules. The bulk and tapped densities are indicative of a powder's packing properties. The flow properties of the cellulose powders were determined using Hausner's Ratio, Carr's Index, Flow rates, and Angle of Repose. The swelling index is a significant pointer to the disintegration property of any powder, as swelling is a mechanism for disintegration[13].

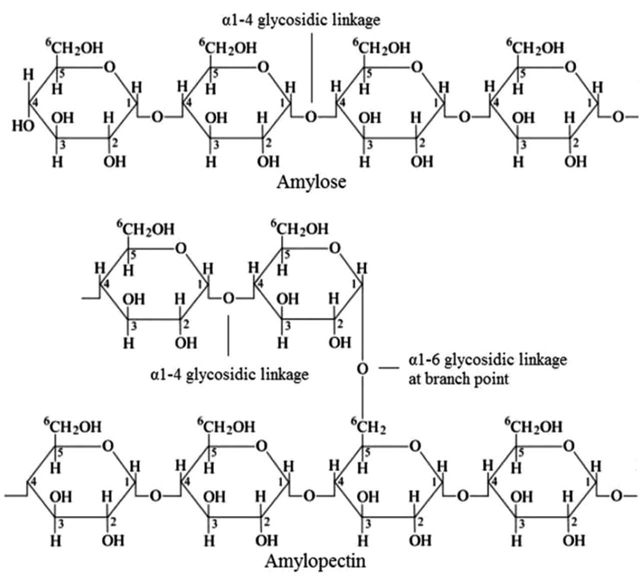

Fig. 1 — The chemical structure of starch constituting natural polymers amylopectin and amylose.

Modified starch

Starches can be modified at the molecular level chemically and physically in order to enhance their properties and extend their application in the food and pharmaceutical industry. Chemical modification is processed through cross-linking, stabilisation and conversion. The chemical structure of native starch is changed due to exposure of different functional groups at different chemical modification methods, resulting in changes in the crystallinity, solubility, gelatinisation, and swelling ability. Cross-linking of starch granules increases its resistance to high temperatures and acidity[14]. Acid hydrolysis, enzyme hydrolysis and oxidation are commonly used techniques to modify starches chemically. Pregelatinization, particle size and moisture adjustment are the typical physical modifications commonly used. Controlled pregelatinization-spray drying, extrusion, and drum drying are the thermal modification techniques of starches. Pregelatinised starches possess better flow, binding, and compressibility, increasing their acceptance in pharmaceuticals[15].

Table 1 briefed the starch modification techniques and their effects on physicochemical properties along with their application in the pharmaceutical industry.

Applications of starches in the pharmaceutical industry

Multipurpose properties are found in starch. In tablet manufacturing, starch extracted from various sources is utilised for various functional qualities. The fact that starch is cheap, eco-friendly, and biodegradable makes it an attractive alternative for further research with other polymeric materials. In the recent era, more emphasis is being imposed on improving therapeutic efficacy through drug delivery system modifications. To attain this goal, currently, modified starch-based nano-formulations, targeted tablets, biofilms, microspheres, transdermal patches and hydrogels have been developed[16]. It is worth

Table 1 — Starch modification technique, its effects on physicochemical properties and applications

Starch source	Modification method	Effects on physicochemical properties	Applications	Reference
Cassava, Rice	Cross-linking	Improve the hydrophobicity, higher viscosity, consistency and thermal shear resistance, Decrease solubility	Disintegrant, Matrix for the controlled drug release	16,17
Plantain	Acetylation	Decrease the crystallinity of the starch, enhance the swelling power, Improve the hydrophobicity, resistance to high temperature, low pH, high shear, increase the stability	Disintegrant, Matrix for the controlled drug release	18,19
Potato	Oxidation	Increase solubility, decrease swelling power and viscosity, low-temperature stability and high clarity	biodegradable film coating	16
Cassava	Pregelatinization	Improve flowability, binding property, and compressibility, increase swelling ability and viscosity	Disintegrant	20

noting that the distinct properties of non-conventional starch nanoparticles enable the development of tailor-made materials that might not be produced from conventional starch sources.

With the exceptions of commercial starches, corn, potato, and wheat, the remaining cereal and tuber starches are looked upon as highly un-commercialised, underutilised, and non-conventional. Non-conventional starches can have technological advantages and properties that benefit several industries, including pharmaceutical[21]. Only the starches obtained from cereals and tubers have been commercialised worldwide, increasing demands in the entire production and distribution chain and influencing costs and environmental sustainability. Utilising these unconventional starches can be a viable solution for regional development, assuring as a revenue source and fostering the area's sustainability.

As stated in Table 2 below, starch often serves as a glidant, diluent, binder, and disintegrant in tablet formulation[8]. The data briefed in Tables 1 and 2 emphasise the great potential of these alternative starch types and their modified starches used as excipients in pharmaceutical formulations.

Pros and cons of non-conventional starches over commercial starches

The most widely used pharmaceutical-grade commercial starch is maize starch obtained from corn plant[31]. Global demand for maize has increased dramatically, which compels countries to import commercial starches at high costs. However, the increasing demand for starch across many industries is driving the hunt for new, unconventional sources of starch to replace commercial starches.

Moreover, recent studies reported allergic reactions caused by tablets composed of maize starch as excipients[32]. The poor compressibility and flowability and high lubricant sensitivity of maize starch have limited its use in direct compression of tablet manufacturing[33]. It needs to be cautious about formulating diabetic formulations using maize starch due to its high glycaemic index which could increase blood sugar level[34]. The necessity for safe and versatile natural excipients increases as users start to have concerns about synthetic polymers and commercial starches.

Non-conventional starch is considered safe and its modified forms may pose certain safety concerns. In most research toxicological studies of modified starches have been ignored. The higher sensitivity of starch to acids and enzymatic attacks makes it limited to use. However, modification of starch enhances its resistivity to enzymatic and acid attack[21]. In comparison to other synthetic polymers and commercial starches, these native starches and their modified starches have a number of benefits, including improvement of solubility, flowability, compressibility, protection from toxicity, improvement in bioavailability and stability, sustained delivery and protection from chemical and physical degradation[21,35]. Only the commercial starches are driving up demand across the whole production and distribution chain, impacting prices and environmental sustainability. Making use of these non-conventional starches can be a good way to support regional development, ensuring a source of revenue and promoting sustainability in the area[22]. However, economic, environmental, and country regulations need to be considered in producing cost-effective, purified alternative starches from these non-conventional starch sources.

Starch from tuber crops

There are root tubers like cassava and sweet potato and stem tubers such as potato and taro yams, etc. Yams are intermediate of roots and stem tubers. All of these types are referred to as tuber crops[36].

Ipomoea batatas

Ipomoea batatas, named sweet potato, contains approximately 70% starch dry weight basis, and it has

Table 2 — Applications of starches as pharmaceutical excipients

Source	Plant part	Botanical name	Application	References
Sweet potato	Tuber	*Lpomoea batatas*	Binder, disintegrant, diluent	22,23
Cassava	Tuber	*Manihot esculenta*	Binder, coating agent	16,17
Yam	Tuber	*Dioscorea* spp.	Binder, disintegrant	24
Taro yams	Tuber	*Colocasia spp.*	Binder, disintegrant	25
Potato	Tuber	*Solanumtuberosum*	Binder, disintegrant, diluent	26
Sorghum	Cereal	*Sorghum bicolor*	Binder, disintegrant	27
Maize	Cereal	*Zea mays*	Binder, disintegrant, diluent	26
Rice	Cereal	*Oryza sativa*	Binder, disintegrant	28
Pearl millet	Cereal	*Pennisetum americanum*	Disintegrant, super disintegrant	29
Pigeon pea	Cereal	*Cajanus cajan*	Binder, disintegrant	30

revealed properties appropriate as excipients in manufacturing tablets[37]. A study on formulating Ethambutol tablets using starch from sweet potatoes showcased that sweet potato starch compared well with maize starch BP. When used at equivalent concentrations in formulations[23]. Sweet potato starch proved to be a good binder. Even though the maize starch showed greater effectiveness as a binder, there was no statistically significant difference in their release properties when used at the same concentration in Ethambutol formulations (p <0.05)[23]. This implies its usefulness as an alternative binder to produce tablets with particular mechanical properties. As per the literature, sweet potato starch reported a high angle of repose, Hausner's ratio, and Carr's compressibility index similar to the commercial maize starch[23]. Therefore, the use of sweet potato starch either as a binder, disintegrant, or diluent might be idyllic in wet granulations. However, improved granule flow of these starches could be allowed for smooth tablet compression.

Another study carried out on the physicochemical characteristics of two modified purple sweet potato starch; pregelatinised and acetylated, showed good flow properties, moisture content, and percentage of compressibility, complied with the requirements of pharmaceutical excipients stated in Handbook of Pharmaceutical Excipients 6th edition and the United States Pharmacopeia 43rd edition. The starch from purple sweet potato has the potential as an alternative disintegrant for tablet formulation, considering the concentration to be added[38].

Manihot esculenta

Cassava or tapioca starch is an odourless, white, tasteless powder isolated from the tubers of *Manihot esculenta*, which contains 65–80% starch. A study indicated that cassava starch serves as a multifunctional excipient such as a binder, filler, and disintegrating agent in tablet dosage form, significantly reducing the manufacturing costs and time for Propranolol tablets[39]. Cassava starch, characterised by low amylose content compared to other types of starches, exhibited a low gelatinisation temperature and high swelling power, rendering it a favourable excipient. Furthermore, due to the higher gel strength of its mucilage, cassava starch has been found to have a greater binding ability than cocoyam and maize starches. According to the literature, cassava starches have superior disintegrant properties than maize starch BP[40]. As a result, cassava starch offers a new approach as a possible disintegrant and is utilised in place of pharmaceutical dosage forms.

The main limitations of natural cassava starch are its poor flowability and high cohesiveness, both of which can be addressed via starch modification[41]. The modified tapioca starches that were investigated as pharmaceutical excipients include carboxymethyl tapioca starch, acid-modified tapioca starch, and cross-linked tapioca starch, pregelatinized tapioca[42]. Modified tapioca starches can be used as a carrier for solid dispersion, a suspending agent, a direct compression filler, a binder, a disintegrant, a matrix forming agent for controlled release tablets, a film coating agent and a carrier for muco-adhesive microsphere[43]. The smoother surface of acid-treated cassava starch may have contributed to the increased tapped density observed after modification. Both native and modified cassava starches exhibit passable flow, as per the values of the angle of repose, Hausner's ratio, and Carr's index, but maize starch shows poor flow, which can be further improved by Granulation, lubricant addition, or oven drying[43].

***Dioscorea* spp.**

Starch content of *Dioscorea rotundata* yam tubers is 61%[24]. Yam starch outperformed maize starch in a research study on the pre-compression analysis of granules, demonstrating slightly better granular flow characteristics. Both the mechanical strength and the disintegration time of the tablets increased with increasing yam starch binder concentrations[24]. Yam starch showed better hardness while the maize starch gave a slightly better friability in the tablets. The study results reported that *D. rotundata* starch had comparable properties to maize starch when used as a tablet binder. In manufacturing tablets yam starch can be regarded as a feasible and efficient alternative binder when extracted at pharmaceutical grade[24].

This yam starch can be further modified to improve its qualities as a useful pharmaceutical excipient in tablet manufacturing. A study reported that starch from *Dioscorea bulbifera* has better flowability after pregelatinization. Also, *D. bulbifera* starch's water-holding capacity, swelling power, and percentage solubility are all enhanced by pregelatinization. It also showed better disintegrant properties of modified *D. bulbifera* starch compared to native *D. bulbifera* starch due to their relatively high swelling power[44].

Colocasia esculenta

Taro/Cocoyam (*Colocasia esculenta*) contains 70–80% of starch on dry basis[45]. A study has shown the potential of cocoyam as a binder in Ibuprofen tablet formation. At compression pressure of 24 Pa and binder concentration of 2% w/w, cocoyam starches can be used as binders in ibuprofen tablets. Under such conditions, less friable tablets are produced, and reduced amounts of materials are used. Starch from Mulola and Mzuzu cocoyam variety is the most appropriate binder for ibuprofen tablets[46].

Another study has demonstrated the efficiency of taro starch and its citrated form as a tablet disintegrant and its further influence on the dissolution of the drug. It was discovered that tablets made with native starch and modified citrated starch were similar to standard maize starch in their qualitative features. Further, according to the disintegration efficiency results, the taro and citrate-modified taro starches both showed tablet disintegrant properties and outperformed the conventional maize starch. According to Carr's index and Hausner's ratio of the study, both native and modified taro starch exhibited poor to very poor flow properties, while angle of repose results showed fair flow. However, the citration of taro starch does not promote significant improvement in the flow property[47].

Table 3 summarises the characteristics of certain native starches extracted from tuber crops such as sweet potato, cassava, yam and taro yam and their modified starches compared to pharmacopeial specifications[48].

Starches from cereals

Starches are the principal constituents of cereal grains. The properties of native and modified cereal starches are described in this section, along with their use in the pharmaceutical industry.

Oryza sativa

Starch constitutes about 90% of milled rice grain[49]. The new varieties of rice (*Oryza sativa*) are commonly available in the world as a result of biotechnological and gene-technological experiments. Hence, the exploration of the modified rice starches from those new varieties has also increased[50]. A study conducted in Thailand used Kum Jao Morchor 107 (KJ CMU-107), a purple pericarp lowland rice variety, to assess their excipient properties. In this study, physically modified starch and four chemically modified starches from KJ CMU-107 rice starch have been used to evaluate the physicochemical and functional properties of the modified starches in comparison with those of native starch to assess their potential as pharmaceutical excipients[51].

Native KJ CMU-107 starch exhibited low swelling power, solubility, and lowest compactibility compared to modified starches. As per this study, all modified starches exhibited lower tapped and bulk densities compared to those of native starch[50]. Cross-linked carboxy methyl cellulose and Carboxy methyl celluloseare two favourable candidates for disintegrant due to the high free swelling capacity values at 37°C. This study revealed that the physicochemical and functional properties of starch can be optimised via physical and chemical modifications. It can optimise fundamental properties such as solubility, swellability, moisture sorption, and water and oil absorption and also mechanical properties such as flowability, compactibility, film-forming ability, and film strength. Therefore, modified rice starches offer opportunities for many applications in the food, pharmaceutical, and cosmetic industries[51].

Pennisetum spp.

Pearl millet (*Pennisetum americanum*) seeds yielded 30–40% w/w starch. According to a study conducted in Sudan, the best starch in the formulation with moisture-sensitive active ingredients is millet starch. There were no significant differences between

Table 3 — Physicochemical features of native and modified starches extracted from tubers

Starch type	True density (g/cm^3)	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Hausner's ratio	Carr's index	Angle of Repose	Flow rate (g/s)
Sweet potato	-	0.56±0.01	0.83±0.00	1.47±0.02	31.96±1.01	30.26±3.67	3.14±0.26
Pregelatinised sweet potato	0.04±0.00	-	0.019±0.00	-	12.73±0.56	29.08±0.54	5.7±0.23
Acetylated sweet potato	0.01±0.03	-	0.04±0.00	-	32.27±0.68	37.7 ± 0.19	6.59±0.22
Cassava	5.07	0.54±0.02	0.69± 0.02	1.31	23.35	31.84±0.48	0.86±0.19
Acid modified cassava	3.14	0.63±0.02	0.80±0.02	1.27	21.22	36.65±0.37	1.78±0.56
Yam	-	0.65±0.00	0.86±0.00	1.32±0.00	24.32±2.03	25.54±6.9	-
Pregelatinised yam	-	0.64±0.01	0.72±0.00	1.13±0.01	11.60±1.63	20.13±1.01	13.74±1.12
Taro	-	0.39±0.11	0.58±0.04	1.42±0.11	37.61±1.33	37.61±1.02	-
Citrate taro	-	0.45±0.11	0.68±0.03	1.36±0.08	36.31±1.09	35.31±1.21	-
Pharmacopeial specifications	1.48	0.45–0.58	0.69 – 0.77	< 1.11	< 10	25 – 30	< 10

Table 4 — Physicochemical features of native and modified starches extracted from cereals

Starch type	True density (g/cm^3)	Bulk density (g/cm^3)	Tapped density (g/cm^3)	Hausner's ratio	Carr's index	Angle of Repose	Flow rate (g/s)
Rice	1.48±0.19	0.42±0.01	0.56±0.01	1.33±0.02	25.00±2.00	45.85±3.00	0.01±0.00
Pregelatinised rice	1.43±0.05	0.51±0.00	0.63±0.04	1.23±0.01	19.05±1.56	39.54±2.33	0.02±0.00
Pearl millet	1.37	0.47	0.78	1.7	39.7	42.03 ± 2.5	_
Acid treated millet	_	0.47±0.30	0.52±0.20	1.11±0.21	11.35±0.11	28.25±0.12	2.30±0.14
Sorghum	_	0.42±1.10	0.49±0.10	1.17±0.19	14.8 ± 0.04	37.00±1.11	6.99±0.15
Carboxymethyl sorghum	_	0.42±1.10	0.48±0.19	1.14±1.05	12.50±0.17	28.00±0.01	7.50±0.00
Pharmacopeial specifications	1.478	0.45–0.58	0.69 –0.77	< 1.11	< 10	25 – 30	< 10

the amylose contents of the maize and millet starch indicating that they have same gelatinisation temperature, gel strength and other physicochemical properties. Both millet and maize starch indicated poor flow and compressibility characteristics. Millet seeds in Sudan gave a high yield of starch and havesimilar physicochemical properties to maize and potato starch[52]. Therefore, millet grain can be a potential source of starch for pharmaceuticals as well as a good alternative to commercial starches.

Another study reported that the particle density of acid-modified *Pennisetum glaucum* starch and maize starch BP showed no variation. Also, acid-modified starch provided satisfactory values for Hausner's ratio and Carr's index, indicating good flow properties. Further, the study showed that modified millet starch, when used as a binder in paracetamol tablets, exhibited similar granule and tablet properties compared to maize starch BP. The acid-modified millet starch can also be used as a disintegrant, an alternative to maize starch BP, because of their comparable dissolution profiles at all test concentrations[53].

Sorghum bicolor

Sorghum (*Sorghum bicolor*) grains contain about 70% starch[54]. A study on physicochemical analysis has reported that modification improved the physical nature of the native starch. The flow properties of the sorghum starch granules were very good, with low repose angles. They exhibited very good flow and better tabletting properties due to a high flow rate with lower cohesive forces and low angles of repose. Carboxymethylated starches obtained from sorghum cereal were well compared with maize starch BP as a potential pharmaceutical excipient. Water solubility, aqueous dispersibility and cold storage stability of starch paste of carboxymethylated starches improved, thus giving tablets the propensity to disintegrate fast. Chemically modified starch has improved physicochemical properties effectively[27].

The properties of starches extracted from cereals such as rice, millet and sorghum and their modified starches have been outlined compared to pharmacopeial specifications[48] in Table 4.

Conclusion

Comparing the reviewed data with the pharmacopeial specifications, the review highlighted pregelatinised starch and acid-modified millet would be beneficial alternatives to commercial starches. These non-conventional starches have shown great promise for use in pharmaceutical formulations and drug delivery systems, especially because of their biocompatibility, safety, cost-effectiveness and degradability. However, the environmental and country regulations, yield of extraction, and high production cost spent for harvesting, extraction and modification techniques could be the challenges in producing cost-effective, scalable alternative starches to commercial starches. In comparison to other synthetic polymers, these native and their modified starches have a number of benefits, such as being secure, affordable, stable, hydrophilic, biocompatible, and biodegradable. Structural changes in these native starches can be improved by introducing different functional groups and converting them to modified starches with significant changes in gelatinisation, solubility, compressibility, and flowability. Furthermore, feasibility studies on the sustainable use of these starches will establish a good market for them commercially in future. This will add value to some of these underutilised crops and also provide starch with tailor-made and special properties for specific applications. Moreover, this review suggests future research, such as exploring the environmental impact or patient outcomes of using these starches in drug delivery systems.

Conflict of interest

The authors report no conflicts of interest.

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