WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 8.084
Volume 9, Issue 10, 1065-1081. Review Article ISSN 2277– 7105

NATURAL STARCHES AS PHARMACEUTICAL EXCIPIENTS: A REVIEW

Nina Varghese* and Dr. M. Komala

Department of Pharmaceutics, School of Pharmaceutical Sciences, VELS Institute of Science Technology and Advanced Studies (VISTAS), Chennai 600 117.

Article Received on
21 July 2020,

Revised on 10 August 2020,
Accepted on 31 August 2020,

DOI: 10.20959/wjpr202010-18289

***Corresponding Author**
Nina Varghese
Department of Pharmaceutics, School of Pharmaceutical Sciences, VELS Institute of Science Technology and Advanced Studies (VISTAS), Chennai 600 117.

ABSTRACT

Starches present in tropical vegetables and fruits have served as a nutritive source of carbohydrate. Most of these crops grow in abundance with little or less agricultural assistance are present with starch in these which are gluten-free carbohydrates. When employed as an excipient can serve the criteria of gluten-free ingredient for the severely effected patients due to reactions created by the presence of gluten components. They have been studied for their excellent pharmaceutical excipient characteristics, such as filler, glidants, binder and disintegrant properties in formulations. Some of these starches can be substituted for commercially available chemically modified starches as excipients. It has been also studies that the modified versions of the native forms of these starches have properties that can be considered for including them as promising candidates in controlled drug delivery systems as well. Starch nanoparticles have been of great interest for drug delivery due to their relatively easy synthesis, biocompatibility, and vast amount of botanical sources. The modified forms of these starches had superior disintegrant properties to commercial super-disintegrant like sodium starch glycolate, which also indicate that they could be used as intra-granular disintegrant in tablet formulations for which rapid release is desired as a substitute for the synthetic disintegrant. Their application as excipients can add value to some of these underutilized crops to provide starch with special properties for specific pharmaceutical need. This review summarizes the current knowledge on the starches extracted from tropical plants that has been studied for their potential usefulness as pharmaceutical excipients.

KEYWORDS: Disintegrants, Super-disintegrant, tropical starches, gelatinization, polymer modification.

INTRODUCTION

Naturally occurring carbohydrate reserves in vegetable sources generally exists in the form of minute granules or cells ranging from 1 to 100µm or more in diameter. They usually consists of 10-38% of total weight of the vegetable, although the proportion often varies depending on the botanic source of the starch, which is also affected by other factor such a s time of collection and cultivation, soil quality and climatic conditions.[1, 2]

Starch obtained from different botanical sources exhibit different characteristics due to variations in amylose – amylopectin ratio, which results in different binder substrate interactions. Starch being the most widely used excipients in food, cosmetic and pharmaceutical industries playing major role as fillers, glidants, thickeners, binders, Disintegrants, gelling, bulking and water retention agent, is an unavoidable fact.[3]

Starches in its pure form is inert in nature; white or pale coloured, and relatively tasteless amd odourless. It is insoluble in cold water and organic solvents such as ethanol, ether and acetone. Starch is hygroscopic in nature and absorbs water when equilibrated under normal atmospheric condition until the amount present is 10 – 17%. It is extracted from the plant or fruit by homogenization followed by separation techniques. The sedimented starch granules can be washed until clean.[2]

The granular structure of starch can be modified physically and chemically to eliminate any undesirable properties, making them more suitable for specific uses.[4,5] Starch has been modified by pregelatinization inorder to produce cold water-swellable starches.[6]

Such modification would be expected to affect various properties of starches, including their swellability and disintegrant properties. Sorghum and plantain starches obtained from Sorghum bicolor L. (Poaceae) and Musa paradisiaca L. (Musaceae) respectively, have been investigated as binders and Disintegrants in tablet formulations.[7,8] It was shown that the swelling and water tetention capacities (parameters likely to have an effect on the didintegration ability of the two starches) of the pregelatinized form of the two starches are higher.[9] It has also been revealed that pregelatinization of the starches affected their abilities as binders and disintegrants.[10-12] With the versatility of starches in various drug dosage

forms, there is the need to continue to develop new starch excipients with suitable properties to meet the special needs of drug formulators.

Topical roots and tubers, grain, cereals and fruits are crops that have served as staple foods for millions of people throughout the world for many centuries. They generally have high starch content (40 – 80%w/w db), which has made them potential sources of industrial starch. Some of these plants grow widely with little or no artificial inputs. They are also highly perishable and have short shelf life due to their high moisture content and the environmental conditions I the tropics. An estimated annual loss of 10-60% of totl crop has been reported for some of these crops.[13]

Many of these indigenous crops are underutilized and farmers have been known to plant them for subsistence rather than for commercial purposes. This situation with respect to agricultural sector can be improved if these crops can be processed into flour and/or starches, which also would be a best way to preserve and reduce loss of these crops.[14]

Commercial starches are obtained from cereals (corn and wheat) and from tubers and roots (particularly potato and cassava) and they dominate the world markets for starches in the food and pharmaceutical industries. Starch extractions from some of these indigenous crops have gained tremendous attention recently as sources of excipients in pharmaceutical formulations. This review attempts to collate the data available on the properties of such tropical starches, highlight their unique properties and their potential applications as pharmaceutical excipients in drug formulation.

CEREALS AND GRAINS

Starch is a multipurpose excipient identified as one of the top ten excipients in demand for various formulations. Corn starch is the most commonly used type of starch used in solid dosage form.[15] Starch has been modified by pregelatinization in order to produce cold water-swellable starch.[16] The sweellability and disintegrant properties of starch can be affected by such modification.

Wheat

Starch is the most abundant carbohydrate component of wheat. Wheat starch has been used in food industry because of its low gelatinization temperature, high viscosity and high water binding capacity.[17] The granular structure of starch can be changed under certain condition

depending on the source of wheat starch. When heated, the starch molecular chains open, allowing them to collide with other starch chains to form a network, thickening the liquid (starch gelatilization). Amylose content was higher in unfractionated starches of both the wheat varieties than the large and small granules. The unfractionated starch exhibited the highest gelatinization enthalpy compared with the isolated starch granules.[18]

Digitaria genus (Fonio) also known as Digitaria exilis, one of one of the oldest indigenous cereal and a popular staple food in West Africa is commonly known as finial millet, hungry rice , hungry millet, which is an annual tropical grass. Fonio grain is a high quality cereal, with a particularly good nutty taste, and a favourable amino acid profile.[19] Though it is classified as millet but until other millets, it is low in protein. Two varities that are common are the white fonio (Digitaria exilis Stapf) also known as acha, fundi, fonio, hungry rice and black fonio (D. iburua Stapf) also known as iburu and petit millet.[20] The two cereals are high in digestible energy, but low in oils and minerals. They are consumed whole or milled into flour and can ne processed into a variety of preparations such as gruels, porridge, beverages, etc.[21]

Fonio starch exhibited a two-stage pattern of swelling and solubility properties similar to other non-waxy cereal starches with Acha starch exhibiting lower swelling capacity than Iburu starch. Rapid viscograph analysis (RVA) of 9% w/w suspension of Acha and Iburu starch showed lower peakchinochloa esculenta), Kodanyard millet (E pasting viscosity and considerably lower break-down viscosity than corn starch. Iburu starch has been shown to have almost similar Carr's index, moisture content, true and tapped densities as maize starch.[22]

Glidant properties of Acha starch has been evaluated in comparison with corn starch and talc in folic acid tablet formulations, in which it showed that both at 2%w/w concentration showed similar glidant properties; which led to the conclusion that Acha starch could serve as an alternative glidant for pharmaceutical granulations.[23]

Millet

The most widely cultivated species worldwide are pearl millet (Pennisetum claucum), Foxtail millet (Setaria italic), Proso millet (Panicum miliaceum) also know as common millet, Broom corn millet ir white millet, Finger millet (Elesine coracana), Indian barnyard millet or Sawa

millet (Echinclou frumentacea), Japanese barnyard millet (Echinochloa esculenta), Kodo millet (Paspalum scrobiculayum), Little millet (Panicum sumatrense).[20]

The millet storage form of carbohydrate in millets in starch and the content varies from 59 to 80% depending on the species. The granukes are small, spherical to polygonal in shape with size ranging from 0.8 to 10µm. the size of the granules and other physicochemical properties of the starches have been shown to vary from one species to the other.

The binding and disintegrant properties of millet starch obtained from *Pennisteum typhoides* have been evaluated in tablet formulations of four drugs with different solubilities - calcium carbonate, sodium bicarbonate, sulfadimidine and chloroquine phosphate.

Millet starch paste at a concentration of 10%w/w dry starch were used as disintegrant for water soluble and insoluble drugs, respectively. The results showed that millet starch paste compared favorably with maize starch as a binder with regards to the table properties. The tablets produced with millet starch exhibited shorter disintegration times than those produced with millet starch exhibited shorter disintegration times than those produced with maize starch suggested millet starch has better disintegrant property than the maize starch. Millet starch was found to be suitable as binder and disintegrant in tablet formulations.[24]

Acetaminophen (paracetamol) tablet formulations containing millet and maize starches were evaluated for the effects of binder concentration, disintegrant concentration and granuke size, and it was found that the disintegrant concentration had the greatest effect on the hardness and disintegration time of the tablets. Interactions were also found between disintegrant concentration and granules size, which considerably reduced the tablet disintegration time.[24]

Starch obtained from Pearl millet (P. glaucum) has also been investigated as a disintegrant in chloroquine tablet formulations. Tablets containing natural and modified forms of Pearl millet starch when employed with varying concentrations of disintegrant, showed decrease in disintegration and dissolution times compared to corn starch BP.[25]

Pregelatinization and acid modification of the starch has also significantly increased the sweeling and water retention capacities of the starches, which also increased the disintegrant properties of both starches. Compared to corn starch, millet starch showed a better disintegrant properties, with the implication that it could be employed in tablet formulations for commercial purposes.[25]

Sorghum

Sorghum belonging to family Gramineae, is a genus of Poaceae, a species of grasses, which is raised for grain, fodder, production of beverages and biofuels.[26] Starch is the major component of sorghum grain, and comprises approximately 70% if dry grain weight.[27] the physicochemical properties of sorghum starch vary widely among the different varieties.[27-30] The amylose and amylopectin content of sorghum starches have been shown to be affected by both genetic and environmental factors.[29, 30]

The disintegration and binding properties if sorghum starch has been evaluated in tablets if magnesium sulphate, calcium carbonate, sulfadimidine and chloroquine phosphate to represent soluble and insoluble inorganic and organic substances respectively. It was forund that sorghum starch was comparable to maize starch in binding and disintegrant properties and better than acaicia as binder.[31]

The solubility of sorghum starch as binder and disintegrant at various concentration in diverse tablet formulations and was found that sorghum starch exhibited about twice the disintegrant power and about the same binding efficacy as maize starch at the same concentrations.[32]

Compression properties and pregelatinization forms of sorghum starch showed that pregeltinization facilitated faster onset of plastic deformation in the starches, but appears to reduce the amount of plastic deformation which occurs during the compression process. This indicated that tablets with pregelatinized starches have lower tensile strength and fracture index than those of the natural form of starch. Tablets containing sorghum starch binders produced tablets with low bond and brittleness than corn starch, which inferred that it could be more applicable as a binder than corn starch when problems of lamination and capping are of more concern than bond strength.[33]

Pregelatinization of sorghum starch binder has shown significant effects on the mechanical properties of tablets, which indicates that sorghum starch could be pregelatinized to improve its material properties and make it more useful as a binding agent especially when particular degree of bond strength and brittleness are required.[34]

Pigeon Pea

The starch content of pigeon pea was 29.7% on a whole seed basis. Starch granules are oval to elliptical to irregular in its microscopy[35, 36] They cantain high levels of protein and the important amino acids – methionine, lysine and tryptophan.[37] The total AM content was 11.1 – 29.3% and the starch exhibited a restricted two-stage swelling pattern and a moderate solubility in water.[36]

When pigeon pea starch are incorporated as binder, tablets showed higher tensile strength and low fracture index and disintegration time than those prepared using corn starch paste. Pigeon pea starch produced strong tablets with minimal lamination and capping tendencies, which inferred that when used as binding agent employing high speed tableting machine with short dwell time are used in the production of pharmaceutical tablets.[38]

FRUITS

Plantain starch

Plantain (*Musa paradislaca*, family *Musaceae*) carbohydrate content can be consumed unripe or ripe. It is used as components in baby food when processed into flour.[39] The unripe fruit contains about 48% starch on dry weight basis, and its physicochemical properties varies depending on the variety of plantain. The amylose- amylopectin content ranges from 16- 24% depending on the variety.[40]

Binding and disintegration properties has been exhibited by plantain starch.[41-42] Plantain starch when incorporated as binding agent in tablet formulation, the tensile strength and disintegration time of the tablets increased with increase in the concentration of the starch. Tablets containing plantain starch had higher tensile strength but lower disintegration time than those containing corn starch as binder. Thus concluding that plantain starch would be more useful when faster disintegration of tablet is desired.

Another study employing plantain starch as binding agent inferred increase in relative density of paracetamol tablets which also led to an increase in the results of tensile strength and disintegration time, but a decrease in fracture index of the tablets.[42] Furthermore, pregelatinized plantain starch has also been helpful as binding agent where bond strength is required with minimal lamination and capping problems.[43]

Breadfruit

Artocarpus cummunis, family *Moraceae* native to Kerala and Malaysia. The fruit is used as a source of carbohydrate. It is consumed in the same way as yam.[44] Breadfruit has 53-76% starch and the extracted starch from the pulp is 98% pure.[45] It AM content was 18 – 28%.[46–48]

The compression properties of breadfruit starch has shown that the starch deform plastically under compression pressure in a similar manner to proprietary starches.[49] Breadfruit starch incorporated in tablet formulation as disintegrant was compared with corn starch BP, showed that breadfruit starch only as exodisintegrant in tablet formulations. Hydration capacity and porosity played a major role in the difference in disintegrant effectiveness of tablets incorporated with breadfruit starch and corn starches.[50]

Sago Palm

Sago palm (Metroxylon), used to make sago starch. The yield of sago starch has been shown to be higher than cassava and corn.[51] Sago palm is a potential source of starch for the pharmaceutical industry because it is economically acceptable, relatively sustainable, environmentally friendly, and uniquely versatile.[51]

The physicochemical properties of sago starch depend on the species and the time of harvest.[52] AM content of sago starch 24-31% and its gelatinization temperature of 69-70^{O}C.[52]

Modification of sago starch has led to alterd physicochemical properties, which has gained its application in food and pharmaceutical industries.[53] It showed good binding properties at different concentartions in paracetamol tablet formulations, when incorporated by wet granulation. Hardness and disintegration time of the tablets increased with increase in starch concentration while the tablet friability decreased.[54]

ROOT AND TUBERS

Starch yielding roots and tubers contain 70-80% water, 16-24%, and trace quantities (<4%) of protein and lipids.[55] Most of thr roots and tubes are grown in the Tropics for edible purpose, many of which have been evaluated as excipients: yams (*Dioscorea* species including *D.alata*, arrowroot (West Indian arrowroot – *maranta arundinacea*), Indian arrowroot (*Curcuma augustifolia*), Tacca (*Tacca leoto petaloides*), Queenland arrowroot.

(*Canna edulis*), ginger (*Zingiber officinate*), yam bean (*Pachyrrhizus erosus* L.Urban) and cocoyam which are the edible root crops belonging to the family Araccae wich includes *Colocasia esculenta* and *Xanthodama sagittifolium*.[56]

Yams

Yams, belonging to genus *Dioscorea*, which include over 600 species[57], are staple root crop cultivated in many countreies. Among which *Dioscorea dumetorum; D. oppositifolis* Thunb; *D. alata; D. rotundata* Poir, *D. bulbifera, D. esculenta* Lour and *D. cayenensis* Lamk are most cultivated and economically important species that have been evaluated as excipients in the food and pharmaceutical industries.[61,62] Yam tubers are rich in starch (70 – 80% dry weight basis).[63] The physiochemical properties of starches obtained from different *Dioscorea* species have shown to vary depending on the *Dioscorea* species.[55, 59- 62]

The starch content in *Dioscorea* consists of 18 to30% AM and the temperature of gelatinization ranged from 70 to 92^{O}C.[63, 64] Starch derived from yam in its original form have been used as binding agent and disintegarnts in tablet formulation and properties has been compared with corn starch in tablet formulation.[65-67] Starches extracte from *D. alata* and *D. rotundata* when incorporated as binding agent in chloroquine tablet formulations were found to give desired dinintegration time, whereas starches derived from ID. Dumetorum *and D. oppositifolia* showed good bond strength which minimized problems of lamination and capping in tablet formulations.[67] Also *D. alata* and *D. rotundata* starches showed better disintegrant efficacy than corn starch, while *D. dumtorum* and *D. oppositifolia* starches showed lesser disintegrant efficacy than corn starch, in chloroquine tablet formulations. Thus concluded that few yam starches had favorable effect as binder and disintegrant compared to corn starch, which could be further investigated for their use in commercial tablet formulation.[68]

Yam starches are also investigated regarding their potential as direct compression excipients in tablet formulations in both its natural and modified forms.[59, 69–71] Natural form of *D. dumetorum* and *D. oppositifolia* starches when employed as excipients in tablets were highly compressible and formed tablets of acceptable crushing force, whereas natural form of *D. alata* and *D. rotundata starches* did not form intact tablets until high compression pressures where applied; which inferred that natural forms of *D. dumetorum* and *D. oppositifolia* starches favoured direct compression.[59] Further it has been proved that these starches when modified by Pregelatinization, acid modification, cross- linking and hydroxypropylation,

showed varying properties which could be applied in drug formulation.[69–71] They also showed controlled release of diclofenac for upto 24hrs when used as excipients in matrix system.[72]

Sweet Potato

Sweet potato (*Ipomoea batatas* L. Lam) is a dicotyledonous plant belonging to the family *Convolvulaceae*, which consists of over 1000 species.[73] Sweet potato roots contain approximately 70% starch dry weight basis.[74, 75] The physiochemical properties of sweet potato starch varies depending on the species, climate, degree of maturity and duration of storage.[76]

The compressional characteristics of sweet potato starch showed plastic deformation when compressed.[77] Sweet potato starch paste when employed as binder in tablet formulation, was found to produce tablets with higher bond strength than corn starch.[78]

Cassava

Cassava (*Manlhot esculenta*Crantz), also known as tapioca is an import carbohydrate source which gives a stringy cohesive paste when gelatinized.[79] The total AM content in cassava starch has been reported to range from 13.6 to 23.8%.[80–84]; and its gelatinization temperature ranged between 59.6 and 87.2 ^{O}C.[80, 85]

Cassava starch has shown plastic deformation during compression, similar to corn starch.[77] The packing and cohesive properties of cassava starch exhibited lowest shape factor which promoted closer packing of particles and could be used in capsule production.[86] As binding agent in paracetamol tablets, cassava starch exhibited stronger binding properties than gelatin BP.[87]

Studies were done on the modified forms of tapioca starch.[88] Starch ganules with better flowability suitable for direct compression was exhibited by natural, cross-linked, and acid – modified tapioca starches prepated by spray dry technique. Among which acid-modified and acid- modified cross-linked tapioca starches proved to be useful fillers in direct- compression tablet preparation.[88]

Curcuma angustifolia

Curcuma angustifolia, also known as Indian arrowroot, belonging to the family *Zingiberacea*, contains 27.5% starch on dry weight basis.[92] Curcuma starch had comparable properties as

corn starch with regard to its bulk density, angle of repose and compressinility index. As binding agent in paracetamol tablet with *C. angustifolia* starch showed acceptable weight uniformity, drug content uniformilty, friability, hardness, disintegration and dissolution results than corn starch.[89]

CONCLUSION

A wide range of application exists for the development of topical starches as pharmaceutical excipients for commercial purposes. The native starches could be modified physically or chemically to exploit their much enhanced property to suit the requirements of pharmaceutical drug formulations.

REFERNCES

1. Hoover, R., Composition, molecular structure and physiochemical properties of tuber and root starch: A critical review. Carbohydr. Polym, 2001; 45: 253-267.
2. Oluwatoyin A. Odeku, Potentials of tropical starches as pharmaceutical excipients: A review. Strach / Starke, 2013; 65: 89-106.
3. Singh, N., Singh, J., Kaur, L., N.S., Gill, B.S., Morphological thermal and theological properties of starches from different botanical sources. Food Chem, 2003; 81: 219-231.
4. Bertolini, A.C., Mestres, C., Colonna, P., Raffi, J., Free radical formation in UV and gamma-irradiated cassava starch. Carbohydr. Polymer, 2001; 44: 269-271.
5. Lee, J.S., Kumar, R.N., Rozman, H.D., Azemi, B.M.N., Flow behavior of sago starch-g-poly (acrylic acid) in distilled water and NaOH-effect of photografting. Carbohydr. Polym, 2004; 56: 337-354.
6. M.K.Kottke, H.R.Chueh and C.T. Rhodes, Comparison of disintegrant and binder activity of three corn starch products, Drug Dev. Ind. Pharm, 1992; 18: 2207-2223.
7. S. Esezobo and V. Ambujam, An evaluation of starch obtained from plantain, Musa raradisiaca, as a binder and disimtegrant for compressed tablets, J. Pharm. Pharmcol, 1982; 34: 761-765.
8. J.S.M. Garr and A.B.Bangudu, Evaluation of sorghum starch as a tablet excipient, Drug Dev. Ind. Pharm, 1991; 17: 1-6.
9. G.Alebiown and O.A.Itiola, Compressional characteristics of native and pregelatinized forms of sorghum, plain and corn starches and the mechanical properties of their tablets, Drug Dev. Ind. Pharm, 2002; 28: 663-672.

10. G.Alebiown and O.A.Itiola, The influence of pregelatinized starch disintegrants on interacting variables that act on disintegrant properties, Pharm. Technol, 2003; 27: 28-34.
11. G.Alebiown and O.A.Itiola, The effect of starches on the mechanical properties of pharmaceutical tablet formulations I, Pregelatinization of starch binders, Acta. Pharm, 2003; 53: 231-237.
12. G.Alebiown and O.A.Itiola, Effect of atches on the mechanical properties of paracetamol tablet formulations II, Sorghum and plantain starches as disintegrants, Acta. Pharm, 2003; 53: 313-320.
13. Shujun, W., Jinglin, Y., Wesyuan, G., Hongyan, L., Peigen, X., New starches from traditional Chinese medicine (TCM) – Chinese yam (Dioscorea oppoita., Thunb) cultivars. Carbohydr. Res, 2006; 341: 289-293.
14. Odeku, O.A., Picker-Freyer, K.M., Analysis of the material and tablet formulation properties of four Dioscorea starches. Starch/ Starke, 2007; 59: 430-444.
15. Shangrew R.F. (1992), Internatinal Harmonization of compendia standards for pharmaceutical excipients. In: Crommelin DJA, Midha K., eds. Topics in Pharmaceutical Sciences. Germany, Stuttgart: Medpharm Scientific Publishers, 205-23.
16. N.Visavarungroj and J.P.Reman, An evaluation of hydroxypropyl starch as disintegrant and binder in tablet formulation, Drug Dev.Ind. Pharm, 1991; 17: 1389-1396.
17. Parker M.L., Kirby A.R., Morris V.J., In situ imaging of pea starch I seeds. Food Biophy, 2008; 3: 66-76.
18. Blazek J, Salman H, Rubio A.L., Gilbert E., Hanley T., Copeland L.; Structural Charcterization of wheat starch granules differing in amylose content and functional charcteristics. Carbohyr Polym, 2009; 75: 705-711.
19. Purseglove, J.W. Tropical crops; Monocoltyledons Harlow, United Kingdom, 1985; 142-144.
20. Oluwatoyin A. Odeku, Potentials of tropical starches as pharmaceutical excipients: A review., Strach/Starke, 2013; 65: 89-106.
21. Coda, R., Cagno, R.D., Edema, M.O., Nionelli, L., Gobbetti, M., Exploitation of Acha (Digitaria exilis) and Iburu (Digitaria iburua) flours: Chemical characterization and their use for sourdough fermentation. Food Microbiol, 2010; 27: 1043-1050.
22. Musa, H., Gambo, A., Bhatia, P.G., Studies on some physiochemicalproperties of native and modified starches from Digitaria iburua and Zea mays. Int. j. Phar. Pharm Sci, 2011; 3: 28-31.

23. Muazu, J., Musa, H., Bhatia, P.G., Evaluation of the glidants property of fonio starch, Res. J. Sci. Eng. Technol, 2010; 2: 149-152.
24. Bangudu, A.B., Akande, O.F., Adewuyi, V., Effect of interacting variables on the compaction performance of paracetamol/millet starch tablets. Pharm. World J, 1991; 8: 87.
25. Odaku, O.A., Alabi, C.O., Evaluation of native and modified forms of Pennisetum glaucum (millet) starch as disintegrant in chloroquine tablet formulations. J. Drug Dev. Sci. Technol, 2007; 17: 155-157.
26. Mutegi, E., Sagnard, F., Muraya, M., Kanyenji, B. et. Al., Ecogeographical distribution of wild, weedy and cultivated Sorghum bicolor (L.) Moench in Kenya: Implications for conservation and crop-to-wild gene flow. Gen. Res. Crop Evol, 2010; 57: 243-253.
27. Jambunathan, R., Subramanian, V., In: Biotechnology in tropical crop improvement. Proceedings of the International Biotechnolgy Worhshop, Patancheru, Inde, 12-15 janvier, 1987; 133-139. Patancheru, ICRISAT.
28. Carcea,, M., Cubadda, R., Acquistucci, R., Physiochemical and rheological characterization of sorghum starch. J. Food Sci, 1992; 57: 1024-1028.
29. Singh, H., Sodhi, N.S., Singh, N., Characterisation of starches separated from sorghum cultivars grown in India. Food Chem, 2010; 119: 95-100.
30. Sarg, Y., Bean, S., Seib, P.A., Pedersen, J.F., Shi, Y., Structure and functional properties of sorghum starches differning in amylose content. J.Agric. Food Chem, 2008; 56: 6680-6685.
31. Deshpande, A. V., Panya, L.B., Evaluation of sorghum starch as a tablet disintegrant and binder. J. Pharm. Pharmacol, 1987; 39: 495- 496.
32. Garr, J.S.M., Bangudu, A, A.B., Evaluation of sorghum starch as a tablet excipient. Drug Dev. Ind. Pharm, 1991; 17: 1-6.
33. Alebiowu, G., Itiola, O.A., Compressional characteristics of native and pregelatinized sorghum, plantain and corn starches and the mechanical properties of their tablets. Drug Dev. Ind. Pharm, 2002; 28: 663-672.
34. Alebiowu, G., Itiola, O.A., The effect of starches on mechanical properties of paracetamol tablet formulations II. Sorghum and plantain starches a disintegrant. Acta Pharm, 2003; 53: 231-237.
35. Lawal, O. S., Hydroxypropylation of pigeon pea (Cajanus cajan) starch: Preparation, funtinal characterizations and enzymatic digestibility. LWT Food Sci. Technol, 2011; 44: 771-778.

36. Hoover, R., Swamidas, G., Vasanthan, T., Studies on the physiochemical properties of native, defatted, and heat-moisture treated pigeon pea (Cajanus cajan L) starch. Carhydr. Res, 1993; 246: 185-203.
37. Oshodi, A.A., Ekperigin, M.M., Functional properties of pigeon pea (Cajanus cajan) flour. Food Chem, 1989; 34: 187-191.
38. Dare K., Akin-Ajani, D.O., Odeku, O.A., Odusote, O.M., Itiola, O.A., Effects of pigeon pea and plantain starches on the compressional, mechanical and disintegration properties of paracetamol tablets. Drug Dev. Ind. Pharm, 2006; 32: 357-365.
39. Foulkes, D., Singer, H., Bond, R.C., The banana plant as cattle feed: Composition and biomass production. Trop. Anim. Prod. (Dominican Republic), 1987; 3: 45-50.
40. Nwokocha, L.M., Williams, P.A., Some properties of white and yellow plantain (Musa paradisiaca Normalis) starches. Carbohydr. Polym, 2009; 76: 133-138.
41. Esezobo, S., Ambujam, V., An evaluation of starch obtained from plantain (Musa paradisiaca) as a binder and disintegrant for compressed tablets. J. Pharm. Pharmacol, 1982; 34: 761-765.
42. Akin- Ajani, O.D., Itiola, O.A., Effects of plantain and corn starches on the mechanical and disintegration properties of paracetamol tablets. AAPS Pharms. Sci. Tech, 2005; 6: Article 57.
43. Alebiowu, G., Itiola, OA., Odeku, O.A., Effects of starches on mevhanical properties of paracetamol tablet formulations. I. Pregelatiization of starch binders. Acta Pharma, 2003; 53: 231-237.
44. Adewusi, S. R. A., Udio, J., Osuntogun, B. A., Studies on the carbohydrate content of breadfruit (Artocarpus communis Frost) from south-western Niferia. Strach/starke, 1995; 47: 289-294.
45. Beyer, R., Breadfruit as a candidate for processing. Acta Hort. (ISHS), 2007; 757: 209-214.
46. Loos, P. J., Hood, L. F., Graham, H. D., Isolation and Characterization of starch from breadfruit. Cereal Chem, 1981; 58: 282-286.
47. Rincon, A.M., Padilla, F.C., Physicochemical properties of Venezuelan breadfruit (Artocarpus altilis) starch. Archivos Latinoamericanos De Nutricion, 2004; 54: 449-456.
48. Akanbi, T. O., Nazamid, S., Adebowale, A., Functional, A. A., Functional and pasting properties of a tropical breadfruit (Artocarpus altilis) starch from lie-lfe, Osun State, Nigeria. Int. Food Res. J, 2009; 16: 151-157.

49. Adebayo, A. S., Itiola, O. A., Compression behavior of breadfruit and cocoyam starches and the mechanical properties of their compacts. West Afr. J. Pharm, 2002; 16: 42-50.
50. Adebayo, A. S., Brown-Myrie, E., Itiola, O. A., l Comparative disintegrant activities of breadfruit starch and official corn starch. Powder Technol, 2008; 181: 98-103.
51. Stantn, R., Have trees and eat them. Food Sci. Technol. Today, 1992; 72: 89-94.
52. Ahmad, F. B., Williams, P. A., Doublier, J., Durand, S., Buleon, A., Physiochemical characterization of sago starch. Carbohydr. Polym, 1999; 38: 361-370.
53. Wattanachant, S., Muhammad, S. K. S., Mat Hashim, D., Rahman, R. A., Suitability of sago starch as a base for dual- modification, Songklanakan. J. Sci. Technol, 2002; 24: 431-438.
54. Satyam, G., Shivani, S., Garima, G., Vivek, P. Sharma, P. K., Isolation and evaluation of binding property of sago starch in paracetamol tablet. Int. Phar. Res, Dev, 2010; 2: 1-8.
55. Hoover, R., Compositition, molecular structureand phys- icochemicall properties of tuber and root starch: A critical review. Carbohydr. Polym, 2001; 45: 253-267.
56. Singh, N., Singh, J., Kaur, L., Sodhi, P., N. S., Gill, B. S., Morphological, thermal and rheological properties of starches from different botanical sources. Food Chem, 2003; 81: 219-231.
57. Coursey, D., Yam, G., An Account of the Nature, Orgin, Cultivation and Utilisation of the Useful Members of the Dioscoreaceae, Tropical Agriculture Series, Tropical Products Institute, Longmans, London, 1967.
58. Shunjun, W., Jinglin, Y., Wenyuan, G., Hongyan, L., Peigen,X., New starches from traditional Chinese medicine (TCM)-Chinese yam (Dioscorea opposite Thunb.) cultivars. Carbohydr. Res, 2006; 341: 289-293.
59. Odeku, O. A., Picker-Freyer, K. M., Analysis of the material and tablet formation properties of four Dioscorea starches. Starch/Starke, 2007; 59: 430-444.
60. Ige, M. T., Akintunde, F.O., studies on the techniques of yam flour production. J. Food Tech, 1981; 16: 303-311.
61. Emiola, L. C., Delarossa, L. C., Physicochemical characteristics of yam starches. Food Biochem, 1981; 5: 115-130.
62. Jayakody, L., hoover, R., Liu, Q., Donner, E., Studies on tuber starches. II. Molecular structure, composition and physiocochemical properties of yam (Dioscorea sp.) Starches grown in Sri Lanka. Carbohydr. Polym, 2007; 69: 148-163.

63. Brunnschweller, J., Luethi, D., handschin, S., Farah, Z. et al., Isolation, physicochemical characterization and application of yam (Dioscorea spp.) starch as thickening and gelling agent. Starch/ Starke, 2005; 57: 107-117.
64. Freitas, R. A., Paula, R. C., Feitosa, J. P. A., Rocha, S., Sierakowski, M. R., amylose contents, rheological properties and gelatinization kenetics of yam (Dioscorea alata) and cassava (Manihot utilissima) starches. Carbohydr, Polym, 2004; 55: 3-8.
65. Eradiri, O., Nassipuri, R. N., Temperature effects on the binding efficiency of starch pastes. Pharmazie, 1985; 40: 180-183.
66. Gebre-Mariam, T., Schmidt, P. C., Some physicochemical properties of Dioscorea starch from Ethiopia, Strach/Starke, 1998; 50: 241-246.
67. Okunlola, A., Odeku, O., Evaluation of starches obtaine from four Dioscorea species as binding agent in chloroquine phosphate tablet formulations. Saudi Pharm. J, 2011; 19: 95-105.
68. Okunlola, A., Odeku, O. A., Comparative evaluation of starches obtained from Dioscorea species an intragranular tablet disintegrant. J. Drug Del. Sci. Technol, 2008; 18: 445-447.
69. Odeku, O. A., Schmid, W., Picker-Freyer, K. M., Material and tablet properties of pregelatinized (thermally modified) Dioscorea starches. Eur. J. Pharma. Biopharm, 2008; 70: 357-371.
70. Odeku, O. A., Picker-Freyer, K. M., Evaluation of the material and tablet formation properties of modified forms of Dioscorea starches. Drug Dev. Ind. Pharm, 2009; 35: 1389-1406.
71. Odeku, O. A., Picker-Freyer, K. M., Chateracterization of acid Modified Dioscorea starches as direct compression excipient. Pharm. Dev. Technol, 2009; 14: 259-270.
72. Odeku, O. A., Picker-Freyer, K. M., Freeze-dried pregelatinized Dioscorea starches as tablet matrix for sustained release. J. Excip. Food Chem, 2010; 1: 21-32.
73. Woolfe, J. A., Sweet Potato an Untapped Food Resources, Cambridge University Press, Cambridge, 1991; 1-12.
74. Lin, L. P., Wheatley, C. C., J., Song, B. F., Studies on the physicochemical properties of starch of various sweet-potato varieties grown in China, J. Cassava Fine Chem. Ind, 1997; 3: 43-76.
75. Lu, G. Q., Sheng, J. L., Application of near infrared reflectance spectroscopy (NIRS) in sweet potato quality breeding, Scien. Agric. Sinica, 1990; 23: 76-81.
76. Tian, S. J., Rickard, J. E., Blanshard, J. M. V., Physicochemical properties of sweet potato starch. J. Sci. Food Agric, 1991; 57: 459-491.

77. Iticia, O., Compressional characteristics of three starches and the mechanical properties of their tablets. Pharm. World J, 1991; 8: 91-94.
78. Odeku, O. A., Awe, O. O., Popoola, B., Odeniyi, M. A., Itiola, O. A., Compression and mechanical properties of tablet formulations containingcorn, sweet potato, and cocoyam starches as binders. Pharm. Technol, 2005; 29: 82-90.
79. Moorthy, S, N., Tuber Crop starches, Tech. Bull. No 18, CTCRI, Trivandrum, India, 2001; 52.
80. Petez, E. E., Breene, W. M., Bhanassay, Y. A., Variations In gelatinization profiles of cassava, sagu and Arrowrrot native starches as measured with different thermal and mechanical methods. Starch/ Starke, 1998; 50: 70-72.
81. Moorthy, S. N., Tuber Crop Starches, Central Tuber crops Research Institute, Sreekariyam, Thiruvanathapuram, Kerala, India, 1994; 1-40.
82. Sivak, MN., Preiss, F., Physicochemical Structure of the Starch Granule, Advamces in Food and Nutritional Research: starch – Basic Science to Biotechnology, Vol. 41, Academic Press, London, UK, 1998; 32-74.
83. Defloor, I., Delcour, J., Physicochemical properties of cassava starch/starke, 1998; 50: 58-64.
84. Rickard, J. E., Asaoka M., Blanshard, J. M. V., The physicochemical properties of cassava starch. Trop. Sci, 1991; 31: 189-207.
85. Zobel, H. F., Molecules to granules _ A comprehensive starch review. Starch/Starke, 1988; 40: 44-50.
86. Itiola, O. A., Odeku, O. a., Packing and cohesive propetiesof some locally extracted starches. Trp. J. Pharm. Res, 2005; 4: 363-368.
87. Itiola. O. A., Amoo, O. A., Effects of cassava starch and gelatin on the compressional characteristics of a paracetamol tablet formulation. Nig. J. Sci, 1998; 32: 83-87.
88. Nwanekezi, E. C., Owuamunam, C.I., Ihediohanma, N. C., Iwouna, J. O., Functional, particle size and sorption isotherm of cocoyam cormel flours. Palistan J. Nutri, 2009; 9: 973-979.
89. Rajeev Kumar, P., Rajeev, R., Anil Kumar, N., Studies on Curcuma angustifolia starch as a pharmaceutical excipients. Int. J. Pharm. Tech. Res, 2010; 2: 2457-2460.