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Assessment of the binding and disintegrant properties of starches obtained from the corns of *Colocasia esculenta* and tubers of *Ipomoea batatas* on diclofenac sodium tablet

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Abstract
The aim of this study was to assess the binding and disintegrant properties of starch obtained from the corns of cocoyam (*Colocasia esculenta*) in comparison to that from the tubers of sweet potato (*Ipomoea batatas*) in the formulation of diclofenac sodium tablets. The starches were isolated and their physicochemical and physicotechnical properties determined. Proximate analysis was performed to determine moisture, protein, fat, and ash contents of the starches. Granules were prepared by wet granulation up to four batches (Batches C1 and C2 containing both starches in varying proportions while C3 and C4 contains only cocoyam and sweet potato starch) respectively. The isolated cocoyam and sweet potato starches appeared as white powders, with pH of 7.9 and 7.7 and the comparative study depicts swelling capacity of 15. 6% and 4.1%, respectively. The flow rate of the granules formed, was in the range of 9.09 - 9.70g/s and the Hausner's ratio and Carr's index were 1.09-1.11 and 8.16 - 10.00 respectively. The compressed tablets for each batch had an average weight of 113.7mg, although the tablets had hardness values within the range 3.8-4 KgF. The percentage losses after the friability test for all batches, was less than 1 and upon assay, the percentage drug content across the batches was within the range of 95-99%. Reference to disintegration, all the tablet batches were not able to disintegrate within 15 minutes and the dissolution profile showed percentage drug release as 51.11%, 47.89%, 44.52% and 37.77% for the batches (C1, C2, C3 and C4) respectively in 60 minutes.

Keywords: Starch, *Colocasia esculenta*, *Ipomoea batatas*, disintegrant, binder, diclofenac sodium, tablets

Introduction
Pharmaceutical dosage forms require the presence of pharmaceutical excipients in their formulation as these excipients are included in the formulation not for their direct therapeutic action, but to facilitate the manufacturing process, enhance stability and for bioavailability or patient acceptability. Pharmaceutical excipients also enhance elegance and integrity of the final product [1].

Natural polymers such as starch have been used as excipients in different pharmaceutical formulations. They are widely available, non-toxic, biodegradable and cost effective. They can also be modified to exhibit various characteristics.

In tablet formulation, it is expedient to choose suitable and appropriate excipients. The excipients used must fulfil certain requirements such as compressibility, good binding properties, flow ability and optimal moisture content.

Starch is one of the most abundant natural carbohydrates stored in plants. It can be isolated from leaves, stems, tubers, seeds, and roots of higher plants where it serves as an energy reserve [2].

Pharmaceutical starches are widely available and are very useful in the manufacture of tablets due to their inertness and inexpensiveness as they could be used for binding, disintegrating, thickening and coating in numerous other applications [3].

Chemically, starches are polysaccharides, composed of a number of monosaccharides or glucose molecules linked together by α-d-(1, 4) and/or α-d-(1-6) linkages and consists of two main structural components, the amylose, a linear polymer in which glucose residues are α-d

-(1, 4) linked typically constituting 15-20% of starch, and amylopectin which is the larger branched molecule with α-d-(1, 4) and α-d-(1-6) linkages and a major component of starch (80-85%) [4].

The use of starch in tablet formulation helps to improve the process ability and enhance drug release behaviour in the body. The performance of a drug is primarily influenced by the disintegration and dissolution behaviour of the powder compact. A disintegrant is an excipient added to pharmaceutically prepared tablets that causes them to breakup and release their medicinal contents (active pharmaceutical ingredient) (API) when in contact with moisture.

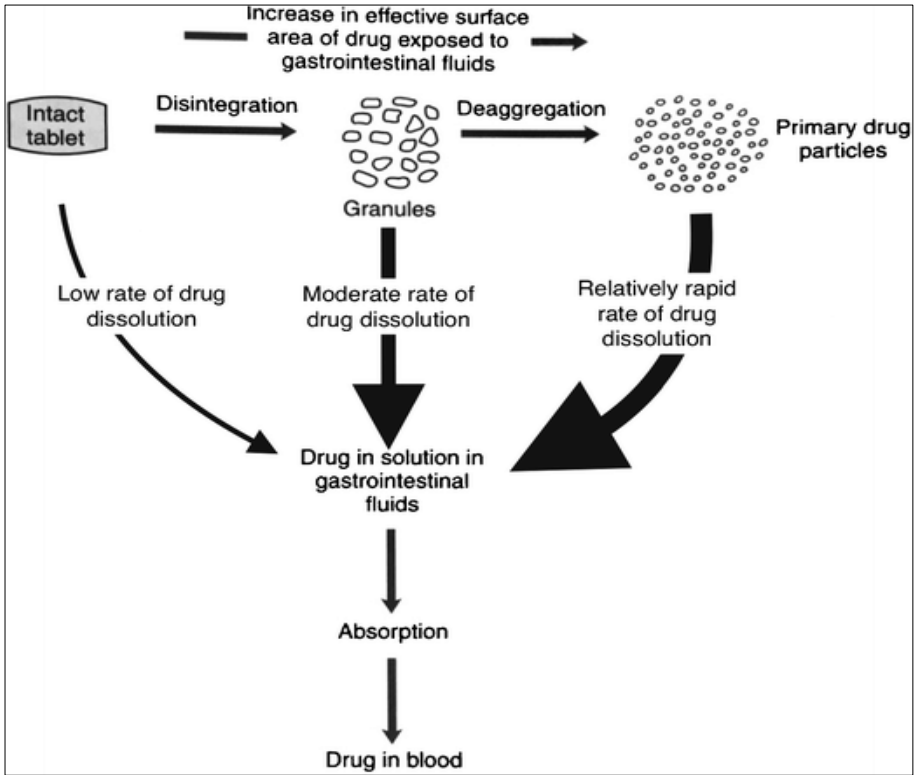

Fig 1: Illustration of tablet disintegration and drug release in the body system [5]

Disintegration involves the mechanical break up of a compressed tablet into small granules upon ingestion and therefore it is characterised by the breakdown of the inter-particulate bonds, which were formed during the compaction of the tablet. The physical changes that take place during the compaction process include: particle rearrangement, elastic deformation, plastic deformation, and fragmentation of particles, as well as, the formation of inter-particulate bonds All these steps may have a direct influence on the disintegration of the powder compact as disintegrants undergoes different mechanisms of action when they come in contact with physiological fluids. The disintegration process is specifically critical for immediate-release dosage forms and is an integral step in ensuring and maximising, the bioavailability of the API from the majority of solid dosage forms [6].

Mechanism of Tablet Disintegration

The first and often the rate-determining step in disintegration is the liquid penetration into the porous powder compact. Liquid penetration does not directly build up the pressure which is necessary to rupture the particle-particle bonds, but it is a prerequisite to initiate other mechanisms such as swelling by a process referred to as wicking. Swelling is one of the most accepted mechanisms involved in disintegration. The swelling is the omni-directional enlargement of particles, which build up pressure, push apart adjoining particles, leads to exertion of stress on the overall systems and finally breaks up the tablet. The dissolution fluid in itself exerts a force in the tablet pores, but this force alone can be too low to be effective, particularly if the bonds between the solid particles are strong. In the presence of a disintegrant, however, the forces exerted by the fluid become appreciable enough to destroy the compact. Strain recovery is another well-known disintegration mechanism. The strain within the tablet is the consequence of forcing macromolecules into a metastable configuration either due to interlocking of the polymer chains or as a result of spontaneous crystallisation during the compaction of a tablet. The stored energy can be released as heat immediately following the compaction or, if this is not or only partially the case, when the polymer comes in contact with a fluid.

Hydration of the polymer gives rise to sufficient mobility for entropy recovery to take place, and hence recovery of the original shape of the polymer molecules. Therefore, strain recovery can be regarded as the reversible viscoelastic process of deformation.

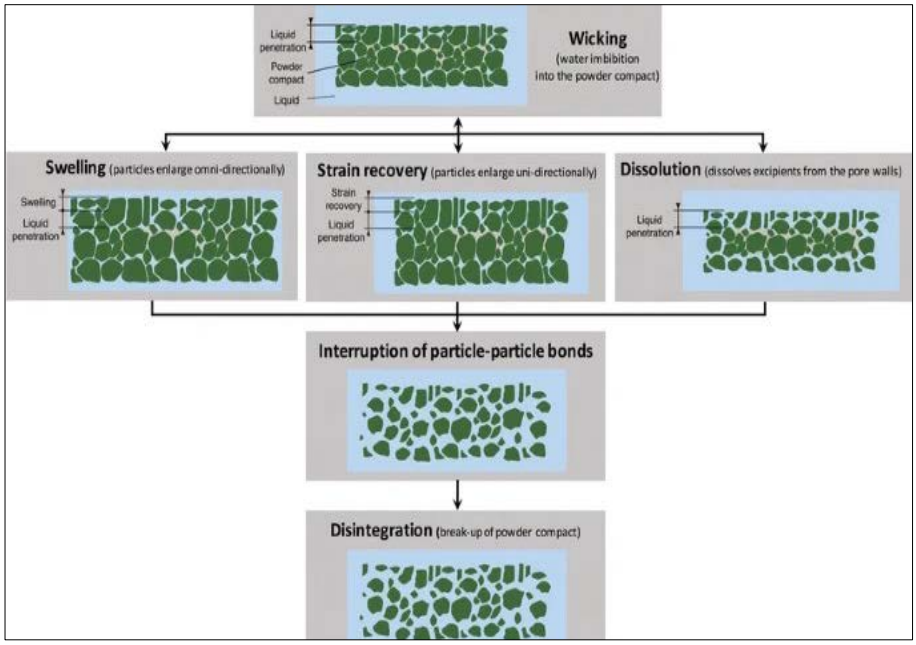

Fig 2: The various mechanisms of disintegrant action [7]

It is uni-directional and directed in the opposite direction of the applied compression force.

Independent of whether the volume enlargement of the polymer powder particles is caused by strain recovery, swelling or a combination of the strain that develops within the porous tablet matrix, the API, is released through the growth of defects into micro-cracks, which in turn increases the (easily accessible) pore space in which water can enter. This process accelerates tablet hydration and, in turn, disintegration.

In addition, the fluid can dissolve or dislodge excipient particles from pore walls, which can significantly affect the porosity and as a result the disintegration performance. Not surprisingly this effect is especially significant for powder compacts incorporating soluble components [8]. Excipient property in Tablet formulation

A pharmaceutical binder is an excipient that holds the ingredients of a formulation. In tablet formulation, binders impart cohesion on the powder mix. This ensures that the tablet remains intact after compression. Binders ensure that tablets can be formed with the required mechanical strength. They are used either in solutions or dry form depending on the other ingredients in the formulations and the method of preparation especially in wet granulation. The quantity of binders used has a considerable influence on the characteristics of the compressed tablets. Increasing the binder concentration invariably raises the disintegration times. Binder products are usually differentiated based on the manufacturing process to be used hence binders are classified into solution binders and dry binders [9].

Diluents are fillers used to make up the volume of tablet if tablet is inadequate to produce the volume. Examples are Lactose, Spray dried lactose, Micro crystalline cellulose (Avicel 101 and 102) etc.

Lubricants are employed to reduce the friction between die wall and tablet, prevent adhesion of tablet to dies and punches. They enable easy ejection of tablets from die cavity and can be classified in to two types: Insoluble: Stearic acid, Magnesium stearate, Calcium stearate, Talc, and Paraffin. Soluble: Sodium lauryl sulphate, Sodium benzoate, PEG 400, 600 and 8000 Glidants aid free flow of granules from hopper to die cavity and minimize friction between particles. Examples include Colloidal Silicon dioxide (Aerosil), Cornstarch, Talc etc [10].

Colocasia esculenta

Description

Colocasia esculenta (L.) Schott, Araceae, is one of the edible aroids distributed throughout the world, particularly in the tropics. It is called ‘taro’ in most parts of the world. Although cultivated as an annual, cocoyam is a perennial herb with a thick, tuberous underground stem whose leaves are simple, broad, and long-petioled [11].

Fig 3: Taro corm

Scientific Classification

It belongs to the Kingdom Plantae, Clade Tracheophytes an Angiosperms and Monocots with Genus Colocasia and Species *C. esculenta*

Constituents

Cocoyam corms contain good-quality protein and are good sources of phosphorus, potassium, calcium, and readily available iron. The corms also have very fine-grained, easily digestible starch, rich ash content and can be a fair source of oils [12]. Taro corm contains starch as the major carbohydrate, accounting up to 70-80% of the whole dry matter.

Local Uses of Taro Corms

The corms can be steamed or boiled as a delicacy. Flour obtained from the corms can be used for edible purposes such as thickener in food preparation.

***Ipomoea batatas* L**

Description

Ipomoea batatas L. (Lam.), is a dicotyledonous plant which belongs to the family Convolvulaceae, Superdivision Embryophyta, Division Tracheophyta, Subdivision Spermatophytina and Class Magnoliopsida [13].

It is a tuberous-rooted perennial crop, usually grown as an annual. Its top herbaceous stems from a running vine up to 4 m long, usually prostrate and slender, with milky juice. The leaves are ovate-cordate, borne on long petioles, palmately veined, angular or lobed, depending on variety, green or purplish. The flowers are quite rare and they are white or pale violet in colour, axillary, funnel-shaped. It also possesses round pods with seeds (1–4 per pod) flattened, hard-coated, and angular [13].

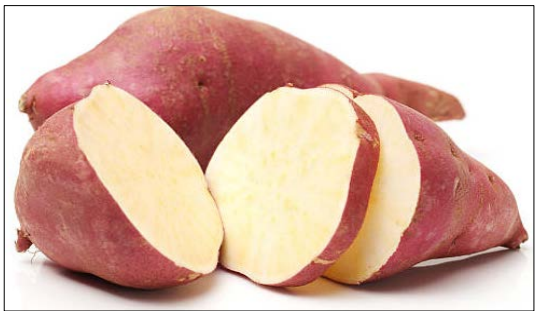

Fig 4: Sweet potato tuber

Constituents

Approximately 80-90% of sweet potato contains dry matter (24-27%) and is made up of carbohydrates, which consist mainly of starch and sugars, with lesser amounts of pectins, hemicelluloses and cellulose [14].

Local Uses

In some tropical areas, sweet potato tubers are staple food crops. It is usually boiled, roasted, fried, and used to prepare various snacks.

Diclofenac

Diclofenac sodium is a potent, synthetic non-steroidal anti-inflammatory drug (NSAID) which is widely used clinically, because of its anti-inflammatory, analgesic and anti-pyretic properties. It is mainly indicated in the treatment of osteoarthritis, rheumatoid arthritis, and ankylosing spondylitis.

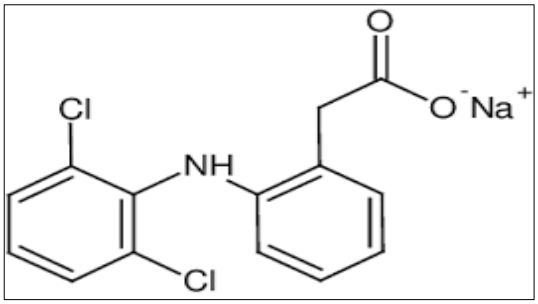

Fig 5: Chemical Structure of Diclofenac Sodium, Molecular formula: $C_{14}H_{10}Cl_2NNaO_2$

Description

Diclofenac sodium exists as a white or slightly yellowish, slightly hygroscopic, crystalline powder. It is sparingly soluble in water, freely soluble in methanol, soluble in ethanol (96 percent), and slightly soluble in acetone and it has a melting point of about 280 ºC [15].

Mechanism of Action

Diclofenac inhibits both cyclooxygenase enzymes, COX-1 and COX-2. The binding to COX isozymes inhibits the synthesis of prostanoids (i.e. prostaglandin [PG]-E2, PGD2, PGF2, prostacyclin [PGI2], and thromboxane [TX] A2). PGE2 is the dominant prostanoid produced in inflammation, and the inhibition of its synthesis by NSAIDs is believed to be the main mechanism of the potent analgesic and anti-inflammatory properties of diclofenac sodium [15].

Pharmacokinetics

Diclofenac is rapidly and efficiently absorbed after conventional oral, rectal or intramuscular administration. After a single 50mg dose of the formulation, mean peak plasma concentrations of unchanged diclofenac are 0.7 to 1.5 mg/L. Like other NSAIDs, diclofenac is highly (≥ 99.5%) protein bound and the mean total volume of distribution is 0.12 to 0.17 L/kg. The drug efficiently penetrates inflamed synovial fluid where high concentrations are maintained compared with plasma concentrations. Diclofenac and its metabolites cross the placenta in animals, and small amounts may be found in the breast milk of women.

Diclofenac sodium undergoes significant first-pass metabolism and only 60% of the drug reaches systemic circulation unchanged following oral administration. It is eliminated principally by hepatic metabolism and subsequent urinary and biliary excretion of glucuronide and sulphate conjugates of the metabolites. The principal metabolite in humans is 4′-hydroxydiclofenac, which possesses negligible anti-inflammatory activity compared with the parent drug. Age and renal or hepatic impairment do not appear to have any significant effect on plasma concentrations of unchanged diclofenac, although metabolite concentrations may be increased by severe renal impairment [16].

Dosage

Diclofenac sodium could be formulated as tablets (prolonged-release and gastro-resistant tablets and capsules) and topical gel. It could be administered in divided doses with meals but safety and efficacy is not established for patients less than 12 years of age [16].

Drug-drug interaction

Plasma concentrations of diclofenac sodium are decreased by concomitant aspirin administration. It decreases the clearance of lithium, and plasma lithium concentrations can become toxic during co-administration. It is inadvisable to administer diclofenac, or any NSAID, with triamterene or methotrexate and it has also been noted to increase plasma concentrations of digoxin [17].

Side Effects

As with other NSAIDs, gastrointestinal problems are the most frequent effects. Other effects include minor CNS symptoms and allergic or local reactions.

Granulation

This is one of the most significant unit operations in the production of pharmaceutical dosage forms, mostly tablets

and capsules. It is the process of particle enlargement by agglomeration technique. Granulation process involves the transformation of fine powders into free-flowing, dust-free granules (large agglomerates) that are easy to compress. Generally, granulation commences after initial dry mixing of the necessary powder ingredients along with the API, so that a uniform distribution of each ingredient throughout the powder mixture is achieved. Granulation transforms the shape, size, surface, and density of powders to improve their physicochemical properties and handling [18].
Types of Granulation includes wet granulation and dry granulation. Granules are formed by passing the mass through screens or sieves and the drying is usually carried out at a temperature below 60º. The dried granules are again passed through a sieve and blended to an appropriate size range for tabletting

Tablets
These are solid single-dose forms which comprise of medicament(s), usually with excipients compressed or moulded into circular shapes with flat or convex faces, or other suitable shapes. They are formulated to release the active ingredients in a way that will achieve the desired effect, and their quality is controlled by a number of standard tests which may include uniformity of weight and content hardness, friability, disintegration and dissolution [19].

Evaluation of Powders/Granules
Organoleptic properties: These are observable properties of a powder which can be determined using the sense organs and involves, colour, smell, taste and texture of the powder.

pH: pH is a quantitative measure of the hydrogen ion concentration in solution and is also referred to as the degree of acidity or alkalinity of aqueous or other liquid solutions. It translates the values of the concentration of the hydrogen ion which ordinarily ranges between about 1 and 10-14 gram-equivalents per litre into numbers between 0 and 14. In pure water, which is neutral, the concentration of the hydrogen ion is 10^{-7} gram-equivalents per litre, which corresponds to a pH of 7 [20].

Swelling Capacity
The swelling capacity of a polymer is determined by the amount of liquid material that can be absorbed by it. The swelling capacity of powders can be determined by the method of Iwuagwu *et al.* (2004) [31]. The formula for swelling capacity (S) is given below:

$S= [(V_v - V_x)/ V_x] \times 100$

Where; V_v = volume of sediment, V_x = volume of tapped dry powder [21]

Swelling Index
The swelling index of the powder can be determined by a modification of the methods of
Bowen and Vadino [22] and Iwuagwu and Okoli (2004) [23]
Swelling index= V_t/V_x
Where; V_t = volume of tapped dry powder, V_x = volume of sediment

Hydration Capacity
A starch gel's entire capacity to hold water under specific conditions is known as its hydration capacity. Water hydration capacity is determined as the maximum amount of water that 1 g of material will imbibe and retain under low-speed centrifugation [24].

Hydration capacity = $W_S/W_D \times 100$

Where; W_S = weight of the sediment formed, W_D = weight of the dry powder

Bulk Density
Bulk density is the mass of bulk solid that occupies a unit volume of a bed, including the volume of all inter-particulate spaces. Bulk density is of great importance for economic and functional reasons. On the other hand, low bulk density, as seen in agglomerated products, influences other powder properties such as flowability and instant characteristics [25].

Bulk density= mass/volume

Tapped Density
Tapped density of a powder is the ratio of the mass of the powder to the volume occupied by the powder after it has been mechanically tapped for a defined period of time. The tapped density of a powder represents its random dense packing [25].

Tapped= mass/tapped volume

Angle of Repose
When granular solids are piled on a flat surface, the sides of the pile are at a definite reproducible angle with the horizontal levelled surface. This angle is called the 'angle of repose' of the material. The angle of repose is important for the design, processing, storage, and conveying systems of particulate materials. Materials with low angle of repose are highly flowable and can be transported using gravitational force or a little energy [26].

Angle of repose, $(\Theta) = \tan^{-1} (2h/d)$

Where; h= height of heap, d= diameter of the base of the heap

Carr's Compressibility Index and Hausner's Ratio
The Carr's Compressibility Index (Carr's Index) and Hausner Ratio are two measures which can be used to predict the propensity of a given powder sample to be compressed, and which are understood to reflect the importance of inter-particulate interactions. These interactions are generally less significant for a free-flowing powder, for which the bulk and tapped densities will be relatively close in magnitude. Poorer flowing materials are characterized by the existence of larger inter-particle interactions, so a greater difference between bulk and tapped densities is observed. The two indices are calculated using the following relations:

Carr's index = Tapped density-Bulk density/Tapped density X 100

Hausner Ratio = Tapped density/ Bulk density

Evaluation of Tablets
Uniformity of Weight/ Weight Variation Test
According to the United State Pharmacopoeia (USP), the test for uniformity of weight is performed by weighing

individually 20 tablets randomly selected from a tablet batch and determining their individual weights. The individual weights are compared with the average weight.

$$\% \text{ deviation} = \frac{\text{Weight of individual tablet} - \text{Theoretical weight of tablets}}{\text{Theoretical weight of tablets}} \text{ X } 100$$

Hardness/ crushing strength Test

Hardness test is also called crushing strength. Tablet hardness has been defined as the force required to break a tablet in a diametric compression test. To perform this test, a tablet is placed between two anvils, and the crushing strength that just causes the tablet to break is recorded.

Generally, the greater the pressure applied in tablet production, the harder the tablets. The formulation composition and manufacturing process may also change tablet hardness. Devices to test tablet hardness include: Monsanto tester, the Strong – Cobb tester, the Pfizer tester, the Erweka tester, and the Schleuniger tester. A force of about 4 kgF is considered the minimum requirement for a satisfactory tablet [27].

Friability Test

The Roche Friabilator is most popular and most reliable instrument for carrying out friability test. This friabulator allows the tablets to roll and fall within the rotating apparatus. Normally, a preweighed tablet sample is placed in the friabilator, which is then operated for 100 revolutions. The tablets are then dusted and reweighed. Any loss in weight is determined. Resistance to loss of weight indicates the tablet's ability to withstand abrasion in handling, packaging, coating, and shipment. Compressed tablets that lose a maximum of not more than 0.5 - 1% of their weight are generally considered acceptable [28].

The test is rejected if any tablet caps, laminates or breaks up in course of the test. The friability of tablets may be influenced by moisture content. Friability loss is usually expressed as percentage loss in weight. It is calculated using the equation:

$$\% \text{ friability loss} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \text{X } 100$$

Disintegration Test

The apparatus used consists of a basket - rack assembly containing dimensions held vertically upon a 10 - mesh stainless steel wire screen. During testing, a tablet is placed in each of the six tubes of the basket, and the mechanical device raises and lowers the basket in the immersion fluid maintained at about 37 °C at a frequency of between 29 and 32 cycles per minute, the wire screen always maintained below the level of the fluid [29].

Dissolution

Dissolution is the process by which drug is dissolved in a solvent and is characterized by a rate (amount dissolved per unit time). *In vitro* dissolution testing of a tablet is very important for many reasons: It guides the formulation and product development process toward optimization of dosage forms for quality control and reliability.

In each test, a volume of the dissolution medium (500 – 900 mL in general) is placed in the vessel and maintained at 37 ± 0.5 °C. Then the stirrer is rotated at the specified speed (50 – 200 rpm). The samples of the medium are withdrawn for analysis based on the proportion of drug dissolved. The tablet or capsule must meet the stated monograph requirement for rate of dissolution example, "not less than 85% of the labelled amount is dissolved in 30 minutes in case of immediate release tablet" [30].

Content Uniformity

Tablet weight cannot be used as an indicator of its potency, except perhaps when the active ingredient is 90 – 95% of the total tablet weight, then the weight variation test would be a satisfactory method of determining the drug content uniformity. The content uniformity of the tablet is more important since the potency of tablets is expressed on labels in terms of grams, milligrams, or micrograms.

By the USP method, 10 dosage units are individually assayed for their content uniformity according to the assay method described in the individual monograph.

The requirements for content uniformity are met if the amount of active ingredient in each dosage unit lies within the range of 85-115% of the label claim and the relative standard deviation is less than 6 [31].

Aim of the Research

The aim of this study is to isolate starch from the tubers of cocoyam and sweet potato and evaluate the starches as excipients associated with binding and disintegrant properties useful in pharmaceutical solid dosage formulation,

Materials and Equipments

Cocoyam and sweet potato tubers (procured from local market at Eneka, in Obio Akpor L.G.A. Rivers State, Nigeria), Diclofenac sodium powder (Pharm. company, China), Sodium Metabisulphite, Conc. sulphuric acid, 0.1N sulphuric acid, 0.1N Sodium Hydroxide, Alpha Naphthol (10% Alcoholic Solution), magnesium stearate, talc, hot Air Oven (New Life, DHG – 9023a, England), Analytical Weighing Balance (Adventurer TM AR 2130, England), Centrifuge, pH meter (Jenway 3510, England), Hardness Tester (Erweka TBH 100, Germany), Friabulator (Erweka TAR 220, Germany), Water Bath, Disintegration Apparatus (Erweka ZT 122, Germany), Dissolution Apparatus (Erweka TBH 600,Germany), UV Spectrophotometer (Jenway 6405 UV, England) and tableting machine (Erweka Single Punch EP-1).

Method

Isolation of Starch (es)

The fresh cocoyam corms and potato tubers were respectively weighed and peeled. The peeled corms and tubers were cut into small pieces and ground thoroughly with a blender. The resultant pulp was soaked in sufficient quantity of distilled water and added with 2ml of 0.1% sodium metabisulphite to prevent oxidation and discoloration of the final product then filtered by passing through a muslin cloth. The filtrate was allowed to sediment and the supernatant layer was decanted. The extracted starch was treated with 0.1N sodium hydroxide for 24 hours to remove ammonium or proteineous compounds. The starch was washed with distilled water severally until the pH was neutral then treated with 0.1N sulphuric acid for 12 hours to remove non nitrogenous substances such as minerals. Then the starch was again washed with distilled water severally until a neutral pH was attained then dried in an oven at 40

°C for 2 days to obtain a dried mass which was weighed, powdered, packaged and stored in a glass jar for further analysis.

Phytochemical Examination: Phytochemical screenings were carried out on the extracted starch (es) to determine their compositions such as: test for presence of starch and carbohydrate.

Test for starch
A 0.1 g weight of the dried isolated cocoyam and sweet potato starches were placed on a clean crucible and a few drops of Lugol's solution were added. Observations for presence of starch was made.

Molisch Test
A 2% dispersion of the isolated starches was prepared with distilled water. A 2 ml of this dispersion was transferred into a test tube and a few drops of 10% alcoholic solution of Alpha Naphthol (Molisch reagent) was added. The test tube was inclined at an angle of 45º and 2 ml of concentrated sulphuric acid was added cautiously. Observations were made and recorded.

Proximate Analysis of starch (es)
Moisture content: This was determined by the gravimetric method as described by AOAC (1990). A measured weight of the sample (5.0 g) was weighed into a previously weighed moisture can. The sample in the can was dried in the oven at 105 °C for 3 h.
It was cooled in a dessicator and weighed and then returned to the oven for further drying. Drying, cooling and weighing were done repeatedly at hourly interval until there were no further diminutions in the weight (i.e. constant weight was obtained). The weight of moisture lost was calculated and expressed as a percentage of the weight of sample analyzed.

$$\text{Moisture content (\%)} = \frac{W2 - W3}{W2 - W1} X\ 100 \quad (1)$$

Where: W1 = Weight of empty can, W2 =Weight of empty can + Sample before drying

W3 = Weight of can + Sample dried to constant weight.

Protein: This determination was carried out following Kjeldahl method as described by Chang (2003) [32].

Total ash content: This was done by the furnaces incineration gravimetric method described by James (1995) [33] and AOAC (1984).

Crude fibre: Crude fibre was determined by the method of James (1995) [33].

Crude fat: This was determined by solvent extraction gravimetric method described by Kirk and Sawyer (1980) [34].

Carbohydrate: This was determined using the method of James (1995) [33].

Evaluation of Physicochemical Properties of *Colocasia esculenta* and *Ipomoea batatas* starches

pH
The pH values of 1% starch suspensions of both cocoyam and sweet potato starch were measured in triplicates using a pH metre and the mean pH obtained was recorded.

Solubility
A 0.1g weight of the starch (es) was respectively weighed into 7 different test tubes. 10 ml of various solvent (water, ethanol, n-hexane, chloroform, acetone and propylene glycol) were respectfully introduced into each of the six test tubes containing the starch sample. The test tubes were shaken and observed for solubility.

Flow rate of mucilage
Mucilage was prepared by dispersing 2 g of the cocoyam starch in 15 ml of distilled water in a beaker. A 10ml of the dispersion was withdrawn using a 10ml pipette and allowed to flow out unaided. The time taken for the dispersion to exit the pipette was recorded. The procedure was repeated for sweet potato starch.

Determination of Hydration Capacity
A 1 g of the starches was in placed in 15ml centrifuge tube and 10ml distilled water was added. The tube was closed properly and the content was shaken for 2 minutes and immediately centrifuged at 1000 rpm for 10 minutes. The supernatant layer was decanted and the weight of the moist starch was recorded. The hydration capacity was determined using the equation below:

$$\text{Hydration capacity} = \frac{W_S}{W_D} X100 \quad (2)$$

Where;
W_S = weight of the sediment formed, W_D = weight of the dry powder

Determination of Swelling Capacity
The tapped volume occupied by 1g of the cocoyam and sweet potato starches, V_x was noted. The individual starch was dispersed in 5ml of distilled water and the volume was made up to 10ml with water. After 48 hours of standing, the volume of the sediment, V_v was estimated and the swelling capacity of each starch sample calculated:

$$S = \frac{(V_v - V_x)}{V_x} x\ 100 \quad (3)$$

Where; V_v = volume of sediment, V_x = volume of tapped dry powder
The swelling index was also calculated using:

$$\text{Swelling index} = \frac{V_t}{V_x} \quad (4)$$

Where; V_t = volume of tapped dry powder, V_x = volume of sediment

Physico-technical Properties of the Starch powder and Granules
Bulk Density: A 10 g weight of cocoyam starch was weighed and transferred into a clean, dry 50 ml measuring cylinder and the volume occupied was recorded. The bulk density was calculated using the equation below:

$$\text{Bulk density} = \frac{\text{mass}}{\text{volume}} \quad (5)$$

Tapped Density

A 10g weight of each starch was weighed and transferred into a clean, dry 50ml measuring cylinder. The measuring cylinder was tapped for 5minutes on a padded table top to a fixed height and the tapped volume was recorded. The tapped density was calculated using the equation below:

$$\text{Tapped} = \frac{\text{Mass}}{\text{Tapped volume}} \quad (6)$$

Angle of Repose

A plastic funnel was clamped on a retort stand at a fixed distance of 3cm from a flat surface. Sufficient quantity of each starch sample was poured through the funnel until the tip of the heap touched the orifice of the funnel. The diameter of the heap was marked and measured. The angle of repose was calculated using the formula below:

$$\text{Angle of repose } (\Theta) = \tan^{-1}(2h/d) \quad (7)$$

Where; h= height of heap
d= diameter of the base of the heap

Hausner's ratio

This was calculated for both starches using the formula below:

$$\text{Carr's index} = \frac{\text{Tapped density-Bulk density}}{\text{Tapped density}} \text{X } 100 \quad (8)$$

Carr's index

This was calculated for both starches using the formula below:

$$\text{Carr's index} = \frac{\text{Tapped density-Bulk density}}{\text{Tapped density}} \text{X } 100 \quad (9)$$

Determination of solubility of diclofenac powder: A 0.1g weight of diclofenac sodium powder was weighed into four different test tubes. A 10 ml of various solvent (water, ethanol, acetone, and methanol) were respectfully introduced into each of the four test tubes containing the powder sample. The test tubes were shaken and observed for solubility.

Preparation of Diclofenac Granules

Table 2: Composition of Diclofenac Granules

Ingredients	C_1 (% w/w)	C_2 (% w/w)	C_3 (% w/w)	C_4 (% w/w)
Diclofenac sodium	86	86	86	86
Cocoyam starch	3.45	1.72	5.18	-
Sweet potato starch	1.72	3.45	-	5.18
Gelatin	1.72	1.72	1.72	1.72
Talc	1.81	1.81	1.81	1.81
Magnesium stearate	1.29	1.29	1.29	1.29
Methyl Paraben	0.17	0.17	0.17	0.17
Cocoyam Starch	0.86	2.59	3.45	-
Sweet potato starch	2.59	0.86	-	3.45

***Targeted weight of tablets for all the batches is 115.8 mg

Addition of exo-excipients

The exo-excipients (exo-disintegrants, lubricant and glidant) were added and mixed properly to the granule based on the formula in the formulation.

Compression of granules

After the addition of the exo-excipients, the mixed granules were compressed into tablets using a single punch tableting machine at a pressure of 4 kg.F. The formed tablets were kept for 24 hours before evaluation to allow for elastic recovery

Quality control of tablets

Uniformity of Weight/ Weight Variation Test

Twenty tablets were randomly selected and weighed individually using an electronic balance. The weights were recorded and the mean as well as the variation in weight were determined.

Friability test

Ten tablets were randomly selected from each batch and dusted gently with a soft brush. The tablets were weighed together and placed in a friabulator set to rotate at 25 rpm for 4 minutes. The tablets were obtained, dusted again and reweighed together. The percentage friablility was calculated following the equation:

$$\% \text{ friability loss} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \text{X } 100 \quad (10)$$

Hardness/ crushing strength test

The hardness of ten tablets from each of the 4 batches was determined using Erweka hardness tester and the mean crushing strength was determined.

Disintegration Test

The disintegration rate of six tablet selected randomly from each of the 4 batches was determined using a BP specified apparatus containing phosphate buffer (pH 6.8) at 37±0.5 ^{o}C. The mean disintegration rate was calculated.

Preparation of standard calibration

A 0.05 mg weight of pure diclofenac powder was placed in a 50 ml volumetric flask, dissolved with phosphate buffer, and made up to the mark with the same solvent. Various dilutions of the stock solution were made to obtain, 0.05, 0.10, 0.15, 0.20, 0.25 and 0.30 mg/ml with the phosphate buffer, and the absorbance determined by UV spectrophotometer at 240 nm. A standard calibration curve of absorbance against concentration was plotted.

Dissolution test

The dissolution rates of the active drug from the tablet were determined using USP apparatus. A 900 ml of freshly prepared medium (phosphate buffer) was transferred into the dissolution jars and maintained at a temperature of 37±0.5 °C. The paddles were set to rotate at 100rpm. And samples withdrawn at 5, 10, 15, 20, 30, 40, 50 and 60 minutes and then analysed spectrophotometrically for diclofenac at 240nm. The samples removed for analysis were replaced with fresh aliquots of the dissolution medium and the percentage drug dissolved was calculated as follows;

$$\text{Concentration} = \text{slope x absorbance} + \text{intercept} \quad (11)$$

Amount of drug released (mg/ml) = concentration x dissolution bath volume x dilution / 1000 (12)

$$\text{Percentage drug dissolved} = \frac{\text{Amount dissolved at time, t}}{\text{Total amount dissolved}} \text{x } 100 \quad (13)$$

Content of active ingredient

Ten tablets were selected at random from each of the four batches, weighed and crushed to fine powder. The powdered drug was transferred into a 50 ml volumetric flask and dissolved with phosphate buffer, and made up to the 50 ml mark with the same solvent. The solution was filtered and 0.5 ml of the filtrate was transferred into a 10 ml volumetric flask and made up to the mark with same solvent. The drug content was determined by measuring the absorbance of the filtrate at 240 nm wavelength, with the UV spectrophotometer.

Results

Table 3: Preliminary Confirmation Test

Test	Observation	Inference
Iodine Test		
Cocoyam starch	Blue-black coloration	Starch present
Sweet potato starch	Blue-black coloration	Starch present
Molisch Test		
Cocoyam starch	A deep violet ring observed at the junction of two layers	Carbohydrate present
Sweet potato starch	A deep violet ring observed at the junction of two layers	Carbohydrate present

Table 4: Proximate Analysis

Parameter (%)	Cocoyam starch	Sweet potato starch
Yield (%)	15.03	7.51
Moisture content	9.02 ± 0.07	8.72 ± 0.03
Crude protein	1.41 ± 0.01	ND
Fat content	0.40 ± 0.01	0.39 ± 0.01
Ash	1.98± 0.02	1.64± 0.01
Crude fibre	0.50 ± 0.01	0.75± 0.02
Carbohydrate (by difference)	86.69 ±0.10	88.50±0.03

Key: ND: Not detected

Table 5: Physicochemical properties of cocoyam and sweet potato starch powders

Parameter	Cocoyam	Sweet potato
pH	7.9	7.7
Density (g/ml) (1% dispersion in water)	1.0026±0.0005	1.0015±0.0003
Swelling Capacity (%)	15.6 ± 6.56	4.1 ± 1.3
Swelling Index	0.87 ± 0.05	0.96 ± 0.01
Hydration Capacity	1.84 ± 0.04	1.83 ± 0.005

Microscopy of starch granules

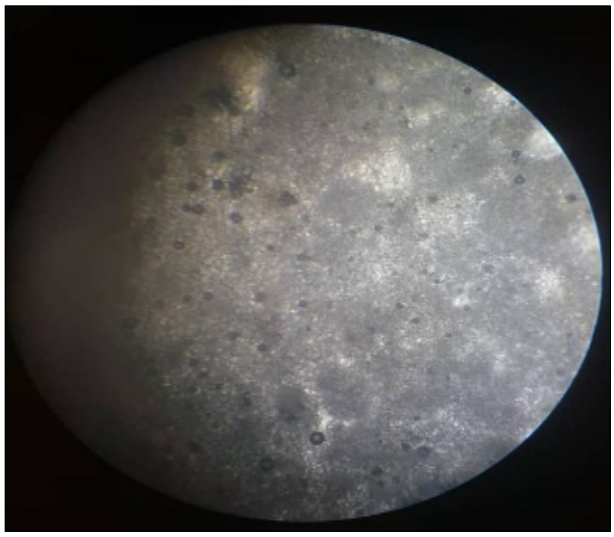

Fig 3: Sweet potato starch

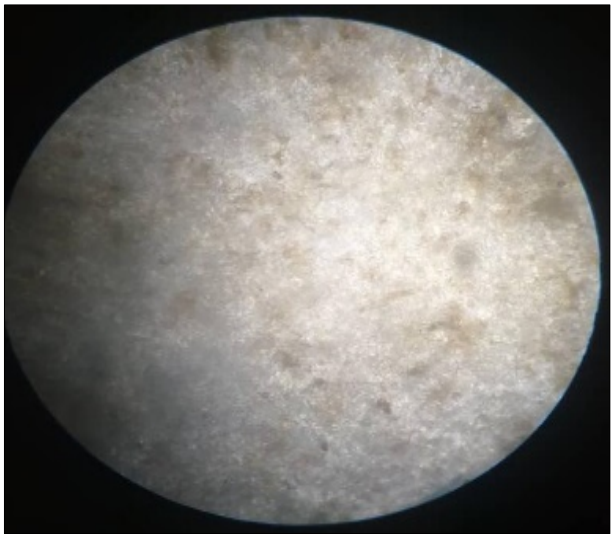

Fig 4: Cocoyam starch

Table 6: Physico-Technical characterization of the starch (es)

Characteristics	Cocoyam starch	Sweet potato starch
Flow rate (m/s) (1% w/v)	2.323 ± 0.005	2.043 ± 0.005
Bulk density (g/ml)	0.47 ±0.02	0.56 ± 0.024
Tapped density (g/ml)	0.67 ± 0.03	0.75 ± 0.03
Hausner's quotient	1.42 ± 0.13	1.34 ±0.03
Carr's index (%)	29.04 ±6.54	25.33 ±1.6
Angle of Repose (θ)	40.6 ± 0.33	40.2 ± 0.33

Solubility Profile of the starch (Es)

The starches from Cocoyam and Sweet Potato were insoluble in both aqueous and non-aqueous solvents although the diclofenac powder was observed to be Sparingly soluble in aqueous medium, soluble in ethanol, slightly soluble in acetone and freely soluble in methanol though all the solvents are inferred to be unsuitable for dissolution of formulated diclofenac powder.

Table 7: Physico-Technical characterization of diclofenac Granules

Granule Property	Granule Batch			
	C1	C2	C3	C4
Flow rate	9.48±0.02±	9.70±0.02	9.66±0.03	9.09±0.02
Bulk Density (g/ml)	0.44±0.02	0.45±0.01	0.44±0.03	0.45±0.01
Tapped Density (g/ml)	0.48±0.01	0.49±0.02	0.48±0.01	0.50±0.01
Hausner's quotient	1.09±0.01	1.09±0.01	1.09±0.01	1.11±0.02
Carr's Index	8.33±0.01	8.16±0.02	8.33±0.01	10.00±0.01
Angle of Repose	33.69±0.01	34.02±0.02	33.25±0.02	33.94±0.01

* Note: C1 (2:1 ratio of cocoyam and sweet potato starches), C2 (1:2 of cocoyam and sweet potato starches) C3 (Cocoyam starch only) and C4 (Sweet potato starch only)

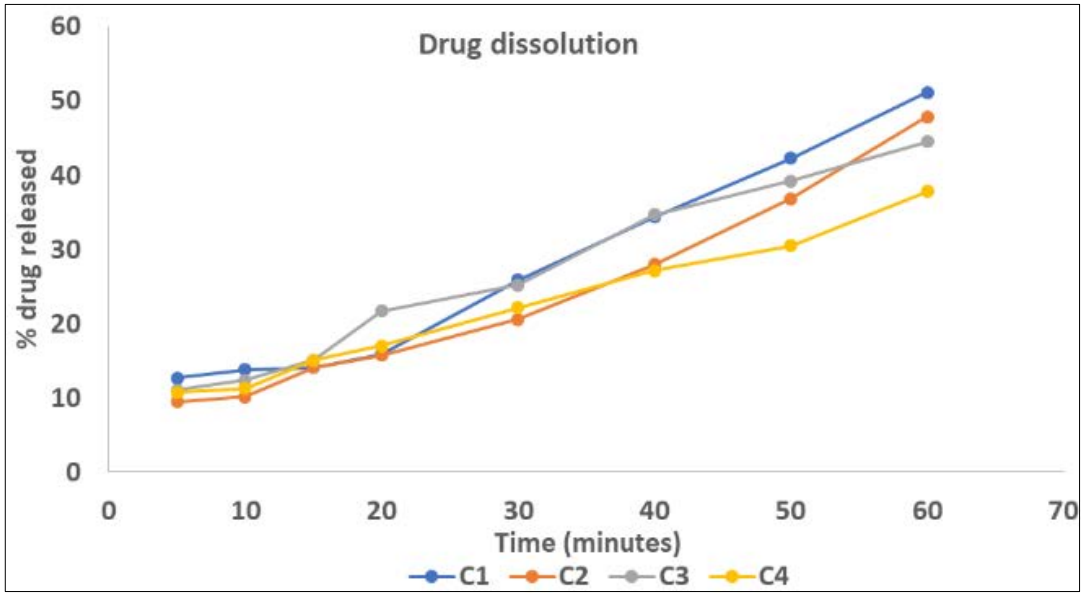

Fig 5: Plot of % drug released against Time (Minutes)

Table 8: Evaluation of Tablet Property

Batch number	C1	C2	C3	C4
Hardness (KgF)	3.8±0.510	3.9±0.370	3.8±0.240	3.8±0.510
Weight Variation (g)	112.8±0.005	113.5±0.005	113.9±0.005	114.7±0.012
Percentage Deviation (%)	±0.004	±0.004	±0.004	±0.015
Friablity (%w/v)	1.00	0.09	0.50	0.33
Disintegration (minutes)	>15	>15	>15	>15
Content of API (%)	98	96	94	99

Discussion

The average percentage yield of the cocoyam and sweet potato starches obtained from the tubers were 15.03% and 7.51% respectively. The isolated starches were subjected to preliminary confirmatory tests, and proximate analysis which were as summarized in Table 3 & 4. The starches subjected to iodine and Molisch tests both produced an intense blue black colouration when treated with Lugol's solution, a confirmation of the presence of starch. On treatment with Molisch's reagent, positive result was obtained from both starches indicating the presence of carbohydrate.

The physiochemical properties and physico-technical characterization of the isolated starches were determined and the results summarized as in table 5 & 6. The obtained results showed that cocoyam and sweet potato starch had swelling capacity of 15.6% and 4.1%, associated with hydration capacity of 1.84 and 1.83 respectively. Hence, the cocoyam starch had a higher swelling and hydration capacity than the sweet potato starch. Swelling and wicking (Liquid penetration by capillary action) are both mechanisms of disintegrant action [7], therefore higher value indicates better disintegrant activity thus inferring the cocoyam starch as a better excipient for pharmaceutical formulations. The more porous a product, the more water or gastric fluid should be able to infiltrate the tablet and dissolve the tablet, allowing the API to be released.

The cocoyam and sweet potato starches were slightly basic, having pH values of 7.9 and 7.7 respectively hence acceptable within the body physiological system hence useful for human consumption.

The bulk densities of the cocoyam and sweet potato starches were 0.47 g/ml and 0.56 g/ml respectively. Bulk density can be influenced by density of the solids, amount of occluded (Air entrapped in the particles) and the amount of interstitial air (Air between the particles), with occluded air being the most important factor for bulk density control [25]. The tapped densities of the cocoyam and sweet potato starches were 0.67 g/ml and 0.75 g/ml respectively. The bulk and tapped density are necessary for the determination of Carr's compressibility index and Hausner's ratio and these respectively gave the values of Carr's index of 29.04% and 25.33% and Hausner's ratio of 1.42 and 1.34 with angle of repose of 40.6° and 40.2° respectively for both starches.

Because these parameters are used to evaluate flowability of powders and granular solids, the starches are assumed to exhibit fair flow.

The diclofenac sodium granules were formulated in four batches as shown in table 2. From the evaluation of the granules as shown in table 6, there was an improvement of flow rate since the powdered samples were not able to flow in their fine state. The granules had bulk densities of 0.44-0 g/ml-0.45 g/ml and tapped densities within 0.48 g/ml-0.50 g/ml. The angle of repose of the granules were within 33.02º-34.02º, flow rates in the range of 9.09 g/s-9.70 g/s, Hausner's ratio was 1.09-1.11 and Carr's index 8.16%-10.00%, hence the granules exhibited excellent flow.

The tablets were evaluated using non-pharmacopoeial (non-official) test and pharmacopoeial (Official) tests. The weight variation test showed average tablet weight across the four batches in the range of 112.7 mg-115.8 mg with percentage deviation of ±0.004% - ±0.015%. According to the USP, tablets from 130 mg to 324 mg should fall within a percentage deviation of ±7.5%. The result obtain was acceptable as the tablets were within this limit.

The hardness of the tablets as determined showed only batch C2 tablets to having an average hardness of 4 kgF which is within standard specifications of 4 kgF-7 kgF while that from other batches were lower. This could be attributed to smaller bulk size of the excipients incorporated. The friability test was also carried out using a Roche friabilator. The percentage friability losses for all the batches were below 1% hence they are all assumed to pass the test depicting that the tablets formed could withstand transportation and handling effects.

The results from the tablet evaluation showed that all from the four batches were unable to disintegrate within 15 minutes. The USP specifies that uncoated tablets should disintegrate within 15 minutes. From studies, tablet disintegration is independent of tablet hardness (and in this case, the tablets were not very hard). However, disintegration can be influenced by the size, hardness of the tablets, lubricant and binder used [19]. Disintegrant action of the tablets also could depend on the swelling and hydration capacity of the disintegrant. In this case, the size and weight of the tablet needs to be improved upon by increasing the bulk size of the excipients for presence of pores and capillaries and adequate control of the compression pressure [8].

The dissolution profile of the tablets showed that within 60 minutes, the percentage drug released was in the order: batch C1 (51%), C2 (48%), C3 (45%) and C4 (38%). The result showed that the batches consisting of combination of two starches (C1 and C2) released more active drug than the ones the starches were used individually (C3 and C4). The rate of dissolution was quite poor in these batches as diclofenac tablets is expected to achieve at least 80% drug release at 60 minutes. This poor dissolution could be linked to inadequate excipient compositions that could increase the porosity and capillary movement in the tablet and enhance water sorption, retention and disintegration.

The percentage active drug content across the batches ranged from 94%-99% and this met the requirements for content uniformity where the amount of active ingredient in each dosage unit must lie within the range of 85-115% of the label claim as specified in the reference standard.

Conclusion: The corns of *Colocasia esculenta* and tubers of *Ipomoea batatas* has appreciable yield of starch although that from *C. esculentus* is more and from physicochemical evaluation both exerted appreciable binding and disintegrant effects especially in solid dosage formulations as observed in that involving diclofenac sodium tablets.

Based on the study carried out therefore, it will be commendable if local cultivation of these starch sources could be encouraged so as to enhance adequate availability and utilization of their starches for improved and increased drug and other product formulation and cushioning of large expenditure on synthetic and imported pharmaceutical excipients and raw materials.

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