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EFFECT OF ACID HYDROLYSIS ON THE PHYSICOCHEMICAL PROPERTIES OF COLOCASIA ESCULENTA STARCH

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ABSTRACT

Starches are widely available and have been very useful as pharmaceutical excipient due to their inertness and cheapness. Modification of native starches ameliorate some deficiencies inherent in them. Acid hydrolysis produce starches with improved fluidity and compressibility. This study was aimed at producing acid hydrolyzed starch (MCS) from *Colocasia esculenta* starch (NCS) modification and to evaluate their physicochemical properties using Maize Starch (MS) BP as a standard. NCS was obtained from a standard procedure of steeping the corms in water. The gelatinization temperature of NCS was determined before production of MCS by acid hydrolysis using 6 N HCl at 52^{o}C for 24 h. The NCS and MCS obtained, was thereafter evaluated for its physicochemical characteristics namely; flow rate, angle of repose, Carr's index, Hausner's ratio, swelling capacity, moisture sorption capacity, moisture content, pH etc. using standard methods. SEM pictures and FTIR spectroscopy of NCS and MCS were carried out to compare changes in their morphologies and functional groups. The *Colocasia esculenta* corms yielded 12.31 % w/w NCS while MCS yielded 88.33 % w/w. The results of the angle of repose (NCS-28.24^{o}; MCS-15.38^{o}), Carr's index (NCS-32.40 %; MCS-20.27 %), Hausner's Ratio (NCS-1.48; MCS-1.25) revealed improvement in their flow properties and compressibility profile in comparison with MS. The SEM pictures and FTIR spectra revealed a positive effect of acid hydrolysis of NCS. The physicochemical properties seen give an insight into the use of the starches as a pharmaceutical excipient.

KEYWORDS: *Colocasia esculenta*, acid hydrolysis, physicochemical properties, pharmaceutical excipient.

INTRODUCTION

According to the International Pharmaceutical Excipient Council, "Excipients are substances other than the active pharmaceutical ingredient which have been appropriately evaluated for safety and are intentionally included in a drug delivery system" (IPEC, 2006). The US Pharmacopoeia-National Formulary categorizes excipients according to the functions they perform in the formulations e.g. Binders, disintegrants etc. (Chaudari and Patil, 2012). The choice of the right excipient can make a lot of difference in the efficiency of the dosage form. Some of the excipients used in the pharmaceutical industry include: diluents or fillers, binders, disintegrants, lubricants, glidants, colorants, flavorants, sweeteners etc. As part of the efforts to reach international harmonization of pharmaceutical excipients, starch has been identified by the Joint Conference on Excipients as one of the top ten excipients used by the pharmaceutical industry (Shangraw, 1992; Adebayo and Itiola, 2003; Okpanachi *et al*., 2012). Starches are widely available and have been very useful in tablet production due to their inertness, cheapness and utilization as fillers, binders, disintegrants and glidants (Adetunji *et al.,* 2006). Starch is a multipurpose excipient in tablet formulation (Adebayo and Itiola, 2003). In recent years, pharmaceutical scientists have been paying increasing attention to the extraction, development and use of starch as pharmaceutical excipients in the formulation of dosage forms (Peerapattana *et al*., 2010; Builders *et al*., 2011; Narkhede *et al*., 2011; Singh and Nath, 2012). Although Maize Starch BP is the most frequently used excipient in tableting, previous studies of other starch sources have shown some promise. Preliminary evaluation of these starches and physicochemical characterization using official and unofficial protocols showed that starches possess some desirable features of good excipients (Adebayo and Itiola, 1998).

Modification of starch involves the alteration of chemical and/or physical properties of native starches. The objective of starch modification is to alter the physicochemical characteristics of native starch to improve functional characteristics. Physical, chemical, enzymatic and biotechnological modification of native starches ameliorate some deficiencies inherent in them (Ashogbon and Akintayo, 2013). The limited application of native starches is due to low shear resistance, thermal resistance, thermal decomposition and high tendency towards retrogration, high syneresis, extreme processing conditions such as pH, temperature etc. The

limitations experienced from native starch may be overcome by various modifications (Jacobs and Delcour, 1998). The basis of starch modification lies in the improvement of its functional properties by changing the physical and chemical properties of such native starch (Okpanachi *et al.*, 2012). Acid hydrolyzed starch is usually prepared by treatment of starch with hydrochloric acid. The gelatinization temperature of starch is initially increased and the transition temperature range is broader after acid hydrolysis (Hoover, 2000).

Cocoyam (*Colocasia esculenta*) is an annual herbaceous hearty succulent plant that belongs to family Araceae. It has a long history of usage in traditional medicine in several countries across the world, especially in the tropical and subtropical regions (Varier, 2004). Today it is grown throughout the West Indies and in West and North Africa. In Asia, it is widely planted in south and central China and is grown to a lesser extent in India. It is now a staple food in many islands of the Pacific. The plant has been known since ancient times for its curative properties and has been utilized for treatment of various ailments such as asthma, arthritis, diarrhea, internal hemorrhage, neurological disorders, and skin disorders (Kalariya *et al.*, 2010). The corms are widely used as an important source of food, excellent source of potassium, carbohydrate and fibers (Aboubakar *et al.*, 2008). The high carbohydrate content of cocoyam and its degree of availability makes it a very good source of starch for both domestic and industrial uses in tropical Africa. Although, they are less important than other tropical root crops such as yam, cassava and sweet potatoes, they are still a major staple in some part of the tropics and sub tropics (Opara, 2002). Cocoyam ranks third in the order of importance after cassava and yam among the root and tuber crops that are cultivated and consumed in rural areas by elderly Nigerians (Olayiwola *et al.*, 2012). Common names of Cocoyam in some Nigerian languages include: Gwaza (Hausa), Koko (Yoruba) and Ede (Igbo).

Fig. 1: Photograph of *Colocasia esculenta* (a) plant and (b) corm.

The aim of this research was to produce acid hydrolyzed cocoyam starch from a native cocoyam starch and to evaluate the physicochemical properties of the starches comparing it with the standard Maize Starch B.P.

METHODS

Collection, Identification and Extraction of *Colocasia esculenta* Starch

Fresh corms of *Colocasia esculenta* were obtained from main Market of Gombe Local Government, Gombe State. The tubers were identified in herbarium of the Department of Biological Sciences Gombe state University (Voucher number GSH 172). The corms were taken to the process Laboratory of the Department of Pharmaceutics and Pharmaceutical Technology, Gombe State University, Gombe, washed, peeled and grated. The grates were washed and weighed, further size reduced using a mixer then grinded to fine pulp using grinding machine. Calico cloth was used to sieve the fine pulp with sufficient distilled water which aided the separation of the starch from chaff. The starch in the excess water was allowed to stay overnight. The supernatant was decanted and little quantities of 0.1 N NaOH solution was added and stirred for about 10 min to dissolve the protein contents. The suspension was then centrifuged at 100 revolution per minute (rpm) for about 10 min. The starch was spread on stainless steel trays and air-dried for 24 hr and then dried at 40 ^{0}C for one hour in an oven (Genlab MINO/30/F, 12B116, UK). The dried starch was size-reduced to fine powder (90-250 µm) using mortar and pestle. It was then weighed and the percentage yield determined. This was then packed in an air tight container, labeled-NCS and stored at room temperature until required.

Preparation of Acid Hydrolyzed *Colocasia esculenta* Starch

Three hundred grams (300 grams) of the native starch powder was suspended in 805.3mL of distilled water. The reaction was initiated by adding 28 mL of 6 N HCl into the suspension and stirred then placed on digital thermostatic water bath set at 52 ^{o}C and the reaction was allowed to proceed for 24 hours while stirring intermittently. Equal volume of distilled water was added at room temperature and centrifuged at 100 rpm for 10 min. The pH was then adjusted with 1N NaOH, sufficient quantity of water was added and then dehydrated with 95 % v/v ethanol. The Hydrolyzed starch was then spread on stainless steel tray and air-dried for 24 hr, then dried in hot air oven (Genlab MINO/30/F, 12B116, UK) at 40 ^{0}C for 1 hr. The percentage yield was determined and starch was then labeled MCS (Okpanachi *et al*., 2012).

Preliminary tests on NCS and MCS

Percentage Yield: The relationship below was used to calculate the percentage yield for NCS and MCS.

$$Percentage\ Yield = \frac{Weight\ Of\ Starch\ Recovered}{Initial\ Weight\ Of\ Sample} X\ 100\ \%$$

Identification Test for Starch (Iodine Test): This was done according to B.P. 2002 specification. One gram (1 g) of each starch sample was suspended in 50 mL of distilled water and boiled for a minute and cooled. A drop of iodine solution was added to 1 mL of the starch mucilage formed and the colour change observed.

Solubility Test: One gram (1 g) of each powdered sample was dispersed in 10 mL each of hot distilled water, cold water, and 95 % v/v ethanol, shaken and allowed to stand for 24 h then 5 mL of the supernatant was taken in each case and heated to dryness on hot plate at 110 ^{0}C. The weight of the dried residue was expressed as a percentage with reference to the volume of the solution, and solubility of the material in the solvent was calculated. The procedure was repeated three times and the mean and the standard deviation was determined.

Determination of pH: A 1 % w/v of each powdered sample was prepared with distilled water and shaken for 5 min and allowed to stand for 10 min. The pH of the supernatant liquid was determined using a pH meter (pH 213, Europe). This was repeated thrice and the mean and the standard deviation determined.

Organoleptic Properties: The colour, odour, taste and texture of the starches (NCS and MCS) were noted.

Physicochemical Evaluation

Determination of Hydration Capacity: This was determined according to the method of Kornblum and Stoopak (1973). One gram (1g) of each of the powder (Y) was placed in a centrifuge tube and covered with 10 mL of distilled water. The tube was shaken intermittently for about 2 hours and left to stand for 30 min before centrifuging at 3000 rpm for 10 min. The supernatant was decanted and the weight of the powder after water uptake and centrifugation (X) was determined. This was repeated three times and the mean was taken along with standard deviation. Hydration capacity was calculated as;

$$Hydration\ Capacity\ (H.C) = \frac{X}{Y}$$

X = weight of 1 g powder after hydration; Y = weight of 1 g powder before hydration

Determination of Swelling Capacity: The Tapped Volume (V_0) occupied by 2.5 g of starch in measuring cylinder was noted. It was then dispersed in 50mL distilled water and left for 24 hr. The Volume of Sediment (V) was then noted. This was repeated three times and the mean was calculated along with standard deviation. The Swelling Capacity (SC) was calculated using the equation;

$$Swelling\ Capacity = \frac{V}{V_o}$$

V = volume occupied by sediment after swelling; V_0 = volume occupied by 2.5 g starch before swelling

Determination of Moisture Sorption Capacity: Ten grams of the starches was spread evenly in Petri dishes, placed in a desiccator with 98 % relative humidity at room temperature. The samples were periodically weighed until a constant weight was attained. This was repeated three times and the mean was taken along with standard deviation. The percentage increase in weight was calculated and taken as the moisture sorption capacity.

$$Moisture\ Sorption\ Capacity = \frac{Final\ Weight\ (g) - Initial\ Weight(g)}{Initial\ Weight\ (g)}\ X\ 100\ \%$$

Determination of Percentage Moisture Loss (Moisture Content): Five grams (5 g) of each powdered sample was heated in an oven at 105 ^{0}C, weighed every hour until a constant weight was obtained. Percentage moisture loss was calculated as a ratio of loss in weight to the initial weight of the sample. The mean and standard deviation of three determinations was calculated.

$$Percentage\ Moisture\ Loss = \frac{Initial\ Weight\ (g) - Final\ Weight(g)}{Initial\ Weight\ (g)} X100\%$$

Bulk Density, Tapped Density, Hausner's Ratio and Carr's Index: Exactly 50 g of each powder sample was weighed and poured through a glass funnel into a 100 mL measuring cylinder at an angle of 45 ^{0}. The cylinder was dropped on a wooden platform from a height of 2.5 cm three times at 2 seconds intervals. The volume occupied by powder recorded as the bulk volume. The cylinder was then tapped on the wooden platform until the volume occupied by the powder remained constant. The mean and standard deviation of three

determinations was calculated. The data generated were used in computing the Carr's index and Hausner's ratio for both powders.

$$Bulk\ Density\ (BD) = \frac{M}{BV}$$

$$Tapped\ Density(TD) = \frac{M}{TV}$$

$$Hausner's\ Ratio\ (HR) = \frac{TD}{BD}$$

$$Carr's\ Index(CI) = \frac{TD\ -\ BD}{TD} X\ 100\ \%$$

Flow Rate: Flow rate was determined by placing each 50 g of the powder retained on the sieve (500 µm for NCS and 710 µm for MCS) in a flow apparatus and allowed to flow through the funnel orifice. The time taken for the powder to flow through the orifice was noted and the flow rate was determined as the ratio of weight (g) to time (seconds). The mean and standard deviation of three determinations was calculated.

$$Flow\ Rate = \frac{Weight\ of\ Sample\ (g)}{Time\ Taken\ To\ Flow\ (s)}$$

Angle of Repose: A plugged glass funnel of orifice diameter 0.8 cm was clamped at a height of 10 cm on a laboratory stand. A 50 g of the powder retained on the sieve (500 µm for NCS and 710 µm for MCS) was weighed and placed in the funnel and then allowed to flow freely. This was repeated 3 (three) times and the mean was taken along with standard deviation. The angle of repose (α) was calculated from the equation:

$$Tan\ \alpha = \frac{H}{R}$$

H = Height of powder heap; R = Radius of powder heap

Gelatinization Temperature: The temperature of gelatinization was determined by preparing 10 mL of 0.2 % w/v starch suspension in 25 mL beaker and heating in a thermostated water bath at 40 ^{0}C. The temperature was raised stepwise by 2 ^{0}C and samples were taken after each rise. The withdrawn samples were observed under light microscope (No. 061270 Ceti, Belgium) to ascertain the temperature at which the granules lost their polarization crosses totally (Mohammed *et al.*, 2009).

Scanning Electron Microscopy (SEM): The SEM was performed to examine the physical structure change of the samples. Each sample was first placed on a sample stub, with a double adhesive attached. It was then coated with 5 nm of gold using a sputter coater by quorum. Thereafter, it was transferred to SEM machine chamber (Phenom Prox Einhhoven-The Netherlands) where it was viewed via a NavCam after some adjustment of focusing and contrast. It was then transferred to SEM mode, focused where the morphologies of different magnification was stored in a USB stick (Okpanachi *et al.*, 2018).

Fourier Transform Infra-red (FTIR) Spectroscopy: The FTIR analysis was carried out to identify changes in organic, polymeric and in some cases inorganic material between NCS and MCS. The FTIR analysis of the samples were carried out using FTIR (Perkin Elmer L1600401 Spectrum Two DT GS, UK). The potassium bromide (KBr) tablet method was employed. Five milligrams (5 mg) of the sample was mixed with 150 mg KBr in a mortar and pestle. The powder mix was compressed using a Sigma KBr press into a tablet shape. The tablet was placed in the sample compartment and scanned at a range of 4000 to 400 cm^{-1} (Okpanachi *et al.*, 2018).

RESULTS

The results of the preliminary results for NCS and MCS are presented in Table 1. The physicochemical parameters of the MCS showed improvement over NCS and MS as revealed in Table 2. The morphology of the NCS and MCS are shown in the SEM pictures in Plates 1 and 2.

The FTIR spectra of NCS and MCS showed characteristics peaks as depicted in Figure 2.

Table 1: Preliminary results for CS and MCS.

Physical Features	**NCS**	**MCS**
Percentage Yield (% w/w)	12.31	88.33
Iodine Test	Positive	Positive
Solubility		
In cold water	Insoluble	Insoluble
In hot water	Insoluble	Insoluble
In ethanol	Insoluble	Insoluble
Organoleptic Properties		
Colour	Light ash	Ash grey
Odour	Odourless	Odourless
Taste	Bland	Bland
Texture	Fine	Fairly coarse
pH	8.71 ± 0.0603	8.58 ± 0.0153

Table 2: Physicochemical Parameters of NCS and MCS *Colocasia esculenta* starches compared with MS.

Properties	NCS	MCS	MS
Hydration Capacity (HC)	2.44 ± 0.0432	2.76 ± 0.1205	1.71 ± 0.0944
Swelling Capacity (SC)	2.37 ± 0.1155	2.81 ± 0.1610	1.46 ± 0.1390
Moisture Sorption capacity (%)	7.20 ± 0.0325	6.05 ± 0.007	6.35 ± 0.0100
Moisture Content (%)	6.66 ± 0.9502	7.95 ± 0.6048	7.35 ± 0.7401
Bulk Density (g/cm^3)	0.61 ± 0.0040	0.66 ± 0.0090	0.55 ± 0.0035
Tapped Density (g/cm^3)	0.91 ± 0.0165	0.83 ± 0.0133	0.83 ± 0.0075
Hausner's Ratio (HR)	1.48 ± 0.0193	1.25 ± 0.0101	1.51 ± 0.0206
Carr's index (%)	32.40 ± 0.8888	20.27 ± 0.6351	33.97 ± 0.9074
Flow Rate (g/s)	5.04 ± 0.5253	4.41 ± 0.3603	DNF
Angle of Repose (^{o})	24.84 ± 0.1812	15.38 ± 0.6972	DNF
Gelatinization temperature (^OC)	53 – 56	46 – 50	54 – 58

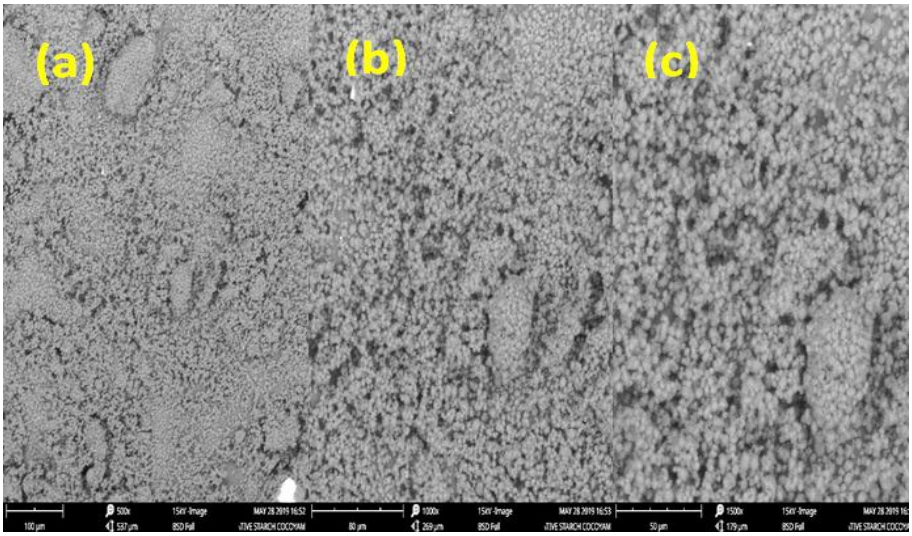

Plate 1: SEM Pictures of NCS at (a) 500x (b) 1000x and (c) 1500x magnifications.

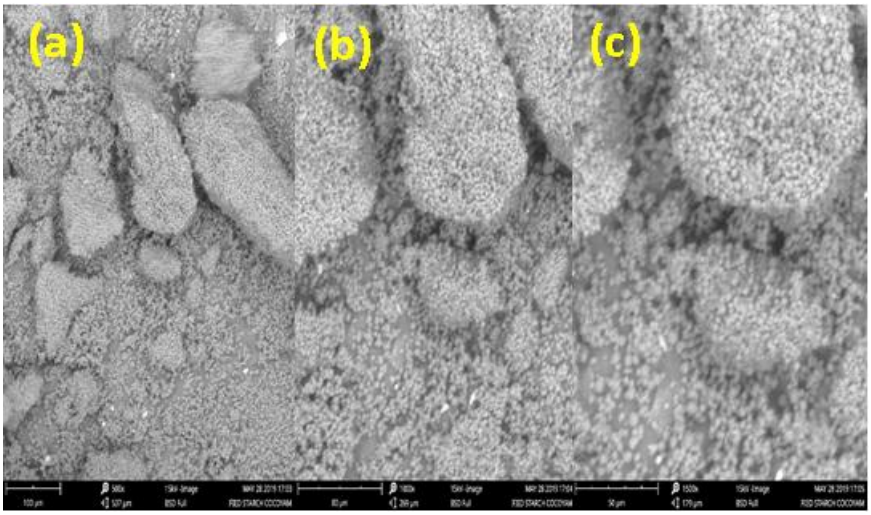

Plate 2: SEM Pictures of MCS at (a) 500x (b) 1000x and (c) 1500x magnifications.

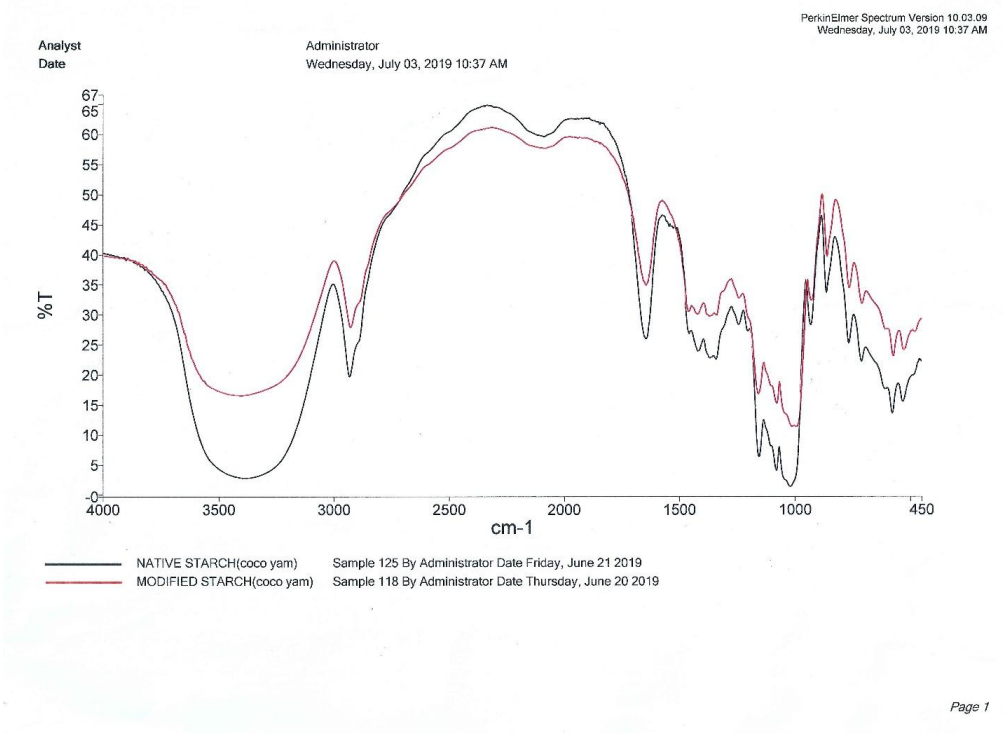

Fig 2: FTIR Spectra of NCS (Native Starch) and MCS (Modified Starch)

DISCUSSION

The result in Table 1 revealed that the percentage yield of NCS obtained from *Colocasia esculenta* (Linn.) Schott and that of the MCS prepared from the NCS were found to be 12.31 % w/w and 88.33 % w/w respectively. This indicated a better yield for MCS over NCS, this could be attributed to numerous processing stages undergone by the NCS during extraction process such as grinding which could have accounted for the losses. Both starches gave a positive result for iodine test as indicated- a confirmatory test for starch. Also, Table 1 revealed that both the NCS and MCS were insoluble in cold water, hot water and ethanol which further confirmed their identity as starch. It has been reported in literature that starch is insoluble in cold water, hot water and ethanol (Musa *et al.*, 2010). This also implied that acid hydrolysis of NCS that lead to MCS has no effect on the solubility of the starch, since both were found to be insoluble. The pH of the NCS and MCS were 8.71 and 8.58 respectively. This implied that the washing of the modified starch after acid hydrolysis was complete because it did not increase the acidity of the starch. Both values although slightly basic are close to neutral pH (7.0). Thus, both starches may be less irritating to the gastrointestinal tract when used as excipients and hence may be suitable in formulation of uncoated tablets. Also, on examination, NCS and MCS were found to be odourless and bland in taste. The Native Starch appeared to be light ash in colour but upon modification it changed to ash grey which

may be due to the effect of acid hydrolysis. The NCS was fine textured while MCS has a fairly coarse texture when felt between the fingers thus enabled it to have a better flow and compressibility characteristics.

In Table 2, the hydration capacities of the NCS, MCS and MS were found to be 2.44, 2.76 and 1.71 respectively. The hydration capacity, also known as water uptake, water holding or water binding capacity, determined the maximum amount of water that 1 g of a material will imbibe and retain under low-speed centrifugation. The ability of a starch to imbibe and retain water translates to its disintegrant property. Thus, based on the result obtained the hydration capacity of MCS > NCS > MS. The swelling capacity of a material is the ability of the material to absorb water and swell up. Materials with high swelling capacity have good disintegrant properties (Caramella, 1991). The results for swelling capacity obtained indicated that MCS had the greatest swelling capacity value thus, may be a better disintegrant compared to NCS and MS. The result revealed that NCS and MCS may be better disintegrants than MS. Powdered starch samples with high moisture sorption capacity may have stability problems (Okafor, 1990). The NCS was found to have the highest value probably due to its porosity and capillary action which is suggestive of a good disintegrant. A decrease in moisture sorption capacity of NCS from 7.20 % to 6.05 % when modified indicated the effect of starch modification on moisture sorption capacity. MCS might cause less instability to moisture compared to NCS and MS. The maximum moisture content prescribed for safe storage by most starch producing countries is 13 % w/w; higher levels of moisture have been known to affect the flow and mechanical properties of starches and can lead to microbial spoilage and consequent deterioration in starch quality. Results obtained in Table 2 revealed that the moisture content values of the starches all fall within acceptable range.

Higher bulk density is advantageous in tableting due to reduction in the fill volume of the die (Alayo *et al.*, 2014). The result obtained were 0.61 g/cm^3, 0.66 g/cm^3 and 0.55 g/cm^3 for NCS, MCS and MS respectively. This indicated that the order of bulk density of the starches is: MCS > NCS > MS. The differences observed in the bulk density values among the three starch samples could be due to differences in their particle sizes and shapes, which affected the packing arrangement and porosity of the powder particles. The tapped density is the maximum packing density of a powder achieved under the influence of well defined, externally applied forces. It can also be used to predict both the flow and compressibility of a

powder. The tapped density is directly proportional to compressibility and inversely proportional to flow property (Martin, 2016). According to the result in Table 2, both MCS and MS have same value of tapped density as 0.83 g/cm^3 while NCS has a higher value of 0.91 g/cm^3. This indicated that starch modification did not affect the tapped density and that both NCS and MCS may exhibit similar flow and compressibility characteristics. The Hausner's Ratio indicates the degree of densification which could occur during tableting with the higher values predicting significant densification of powders (Alayo *et al.*, 2014). It is an indirect measurement of powder flow. Hausner's Ratio greater than 1.25 indicates poor flow (Ohwoavworhua and Adelakun, 2005). The results obtained as presented in Table 2 revealed that only the modified starch has a good flow. This indicated that MCS may be a good candidate for direct compression. The Carr's Index (also known as compressibility index) is also an indirect method of powder flow assessment. According to Remington (2005), the maximum acceptable value for Carr's Index is 15.0 %. The lower the Carr's Index of the material, the better the compressibility and flowability (Carr, 1965). The results showed that Carr's index values for all starches were above maximum acceptable value, which indicates poor compressibility and flowability. The Carr's index for MCS is closer to the acceptable value as compared to NCS and MS.

According to Remington (2005), flow rate < 5 g/s is considered good for pharmaceutical powders. It is essential in determining the ability of powder to flow as a direct compression excipient. The NCS and MCS failed to flow when various particle size distributions were present. When sieved and separated into various particle sizes, the starch particles retained on sieve size (500 µm for NCS and 710 µm for MCS) were the smallest sized starch particles found to flow, hence used for the flow determination. The flow rate result was 5.04 g/s for NCS and 4.41 g/s for MCS. Maize Starch particles were too fine and thus failed to flow for flow rate determination. This shows that MCS has a good flow rate compared to NCS. According to USP (2007), powders with good flow property should have an angle of repose ≤ 30^o while powders with poor flow have an angle of repose ≥ 40^o. The angle of repose could be used as a qualitative measure of the cohesiveness or the tendency of powdered or granulated materials to flow from hoppers through the feed frame into tableting machines. Such uniformity of flow will minimize weight variations in tablets production. Both NCS and MCS retained on 500 µm and 710 µm sieve sizes had a good flow because their angle of repose was ≤ 30^o.

Starch gelatinization is a process of breaking down of the intermolecular bonds of starch molecules in the presence of water and heat, allowing the hydrogen bonding sites (the hydroxyl hydrogen and oxygen) to engage more water. Determination of gelatinization temperature of starch is significant because caution needs to be taken at the temperature when the starch loses its properties under the influence of water and heat. This is particularly important when it comes to drying a blended powder mass during wet granulation. If the gelatinization temperature is exceeded by drying process, the physicochemical property of the starch when used as a binder or disintegrant will be affected. The gelatinization temperature of NCS, MCS and Maize Starch obtained will guide the choice of temperature for unit operations (e.g. drying) during tableting process.

The SEM pictures in Plates 1 and 2 did not reveal well-defined lattices structure and shape. However, the morphology of SEM pictures of Plate 2 appeared to show some slight improvement in the shape of the starch structure. This can be attributed to the modification of NCS by acid hydrolysis.

The FTIR spectrum of NCS showed characteristic peaks at 3392.53 and 2932.60 cm^{-1} while the FTIR spectrum of MCS showed characteristic peaks at 3411.41 and 2930.83 cm^{-1}. This signifies the presence of -ROH (alcohols) and -RCOOH (carboxylic acids) respectively present in both starches. There were no changes or formation of new characteristic peaks after modification of NCS to MCS, which implied that the basic chemical composition of NCS was not altered as a result of the acid hydrolysis. However, the broad band due to the large –ROH bonding spectrum noticed in NCS appeared to have been absorbed in MCS due to the effect of the modification by acid hydrolysis.

CONCLUSION

It can be concluded that NCS and MCS obtained from Cocoyam (*Colocasia esculenta* Linn.) compared well with Maize Starch B.P. as alternative excipients in solid dosage formulation. It was found that the physicochemical properties of NCS as tablet excipient are better than those of Maize Starch. The physicochemical properties of MCS produced starch with improved flow and compressible properties in comparison to NCS and MS. Thus MCS can be used as an alternative pharmaceutical excipient to Maize Starch B.P in solid pharmaceutical dosage formulations.

CONFLICT OF INTEREST

The authors declared that they have no conflicting interest

AUTHORS CONTIRIBUTION

Ifeanyi V. Emenike, Gideon O. Okpanachi and Abdulkarim Abubakar- Research concept and design, collection and/or assembly of data, data analysis and interpretation, writing the article, critical revision of the article, final approval of the article.

Ademola R. Oduola, James A. Bwala and Umar F.G. Zarumai.-data analysis and interpretation, critical revision of the article, final approval of the article.

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