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Research Article

Physicochemical and Excipient Characteristics of a Polymer Isolated from the Seeds of Watermelon *(Citrullus Lanatus)*

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Abstract

This study was aimed at isolating, characterizing and evaluating the excipient functionalities of a polymer from watermelon seeds. After oil extraction, the marc was dispersed in water, agitated, filtered, the polymer harvested as the sediment in the filtrate and purified. The polymer was characterized; used as excipient in tablet formulation; and tablets' qualities were assessed using standard protocols. Physicochemical tests revealed polymer as non-polysaccharide, amorphous biomaterial with melting point: 230.7oC, particle density: 1.70 g/ml, pH: 6.66, swelling index: 51% and toxic metals contents below official limits. Properties of granules and tablets formulated with polymer as binder were similar to those formulated with corn starch as binder. Corn starch was a significantly better ($p<0.05$) disintegrant with PVP as a binder at concentrations greater than 2% w/w. This difference notwithstanding, the dissolution profiles of the tablets were similar. The polymer was a protein, swelled better than corn starch and functionally compared well as tablet excipient.

Keywords: Watermelon seeds, new polymer, physicochemical characteristics, excipient functionality

Introduction

The formulation of active pharmaceutical ingredients (API) for administration through the oral route has predominantly been as solid dosage forms (tablets, capsules and powders) because of their obvious benefits [1-2], thus oral solids will remain relevant in the management of various ailments or as diagnostic aids. Oral solids are composites of various ingredients whose functionalities synergise to ensure the effective delivery of the API. In the formulation of immediate release/conventional tablets, binders, disintegrants and lubricants are indispensible to the formulator. Binders and disintegrants are mainly of natural origin and could belong to gums/mucilages, starches, celluloses or proteins; however, most of these excipients are polysaccharides. The polysaccharides are of plant origin whereas proteinous excipients may be derived from both plant and animal sources. Plant seeds contain proteins in variable quantities and are usually part of the fibrous components left over after the extraction of the primary product of interest, which in most cases is oil. In some extraction operations the fibrous marc is used as animal feed, whereas in other settings it ends up as organic manure. In the case of seeds from *Citrullus lanatus* Thunb. Matsum and Nakai, Family, Cucurbitaceae Juss., commonly known as watermelon [3], the marc may serve as animal feed or manure depending on the economic value placed on it by the entrepreneur. Watermelon seed is native to Africa and particularly common in West Africa, although currently its cultivation spans the entire continents of the world where climate conducive for its propagation exists. The wide cultivation of watermelon hinges on the demand for its juicy fruit, which is low in calorie but high in essential nutrients [4]. Apart from the sweet pulp of watermelon that is highly relished, its seeds are also very valuable, although not as popularly consumed. Its oil is currently the primary product of interest, being marginally exploited as raw material for the cosmetic industry [5]. After the extraction of oil from the seed powder, the marc is usually discarded or in some cases used as animal feed or manure. There is however a component that can easily be isolated from the marc before being used as animal feed and subsequently, animals' excreta can be utilized as organic manure or source of fuel. This cycle ensures more efficient utilization of the products from watermelon. The aspect that involves the isolation of the neglected component from watermelon seeds after oil extraction and the evaluation of its physicochemical and excipient characteristics in pharmaceutical tablet formulation informed the quest for this study.

Materials and Methods

Materials

Watermelon seeds were purchased from Zuba fruit market Abuja, Nigeria and authenticated by Mr Patrick Obi of the pharmacognosy department, Madonna University Elele, and given the Voucher number: MU/PHGSY/20/002. Ibuprofen powder (Novachem, Wuhan China), polyvinyl pyrrolidone K 15 (Fluka, USA), hydroxypropyl methylcellulose (medium viscosity grade, Fluka, USA), corn starch B.P., microcrystalline cellulose PH 101, diethyl ether, 96% ethanol, methanol (Sigma-Aldrich, Germany), magnesium stearate (BDH Chem.,UK), lactose monohydrate (Fluka Netherlands). Other reagents are of analytical grade.

Extraction of Polymer from Watermelon Seeds

The watermelon seeds were sorted by handpicking, dehulled manually and milled with a blender (Panasonic MX 337N, Japan). Thereafter, 500 g of the powder was dispersed in 2000 ml of diethyl ether inside a Winchester bottle and allowed to stand for 24 h with intermittent shaking every 1 h for the first 12 h and then every 4 h for the next 12 h. The mixture was filtered after 24 h using a colourless polyester filter cloth. The filtrate was set aside for oil recovery by rotary evaporation process, while the residue was washed into a stainless steel bucket using 4000 ml of distilled water. The resulting residue-water mixture was stirred with a mixer (Kenwood, model-OWHM400020, Japan) for 15 min and filtered using the filter cloth. The filtrate was allowed to stand for 6 h and the supernatant carefully

decanted to reveal the polymer cake. The polymer was washed four times by shaking for 1 h with 1000 ml of methanol each time using a shaker (Digital orbital and reciprocal shaker, KS / HS 501, Thomas Scientific, USA) and air dried at ambient temperature (34oC) for 48 h. The polymer was powdered and redispersed in 1000 ml of ethanol, shaken for 1 h and filtered. This treatment with ethanol was repeated thrice before the finally washing with 2000 ml of distilled water thrice and air drying at 34oC under forced convection current provided by a fan for 48h. The resulting polymer flakes were powdered and oven dried at 50oC (Chromatograph oven: Coslab AN ISO 9001-2000, India) to a constant mass, sieved (150 μm sieve) and then stored in an air tight container over silica gel.

Qualitative Phytochemical Analysis of the Polymer

The presence of cellulose, starch, reducing sugars, protein, flavonoids, saponins, glycosides, steroids, terpenoids, phenols/tannins and alkaloids in the polymer was investigated using established methods [6].

Determination of Heavy Metal Content

This was conducted in accordance with standard protocols [7, 8] using an atomic absorption spectrometer (Varian AA 240, Netherlands).

Determination of LOD, Swelling Index, Ash Value, pH and Particle Density

Loss on drying (LOD) was determined using BP method [9], swelling index (new polymer, corn starch BP and microcrystalline cellulose), ash value and particle density were determined by reported techniques [10 -12], while the pH of a 1.0% dispersion of the new polymer in distilled water was evaluated with a pH meter (Corning, model 10 England).

Fourier Transform Infrared (FTIR) Spectroscopy

The FTIR analysis of sample was carried out using the apparatus FTIR-8400S spectrometer (Shimadzu, Japan). Two milligrams (2 mg) of sample and 200 mg KBr were powdered with an agate mortar and pestle, and compressed into a pellet using the pellet press. The resulting pellet was mounted on the sample holder and the system was purged with nitrogen gas. Scanning was conducted in the range of 4000 to 400 cm-1 with a resolution of 1 cm-1.

Differential Scanning Calorimetry (DSC) Aanalysis

DSC characterization of the polymer was conducted using the apparatus Netzsch DSC 204 F1 Phoenix (Nietzsche Germany). Four milligrams (4mg) of sample was carefully weighed using the analytical balance (Mettler Toledo AB54, Switzerland) and sealed in aluminium pan. Calibration of the calorimeter was done with indium and the purge gas was nitrogen. Heating of the sample was carried out at the rate of 10°C/min from 30°C to 400°C under nitrogen flow rate of 20 ml/min, followed by cooling back to 30°C at the same rate.

Preparation of Ibuprofen Granules

The granules were prepared with watermelon polymer (WMP) paste or corn starch BP paste (control) as binder at various concentrations (Table 1) with 12.5% w/w corn starch BP as disintegrant incorporated intragranularly. To study the WMP's disintegrant property, polyvinyl pyrrolidone (PVP) or hydroxypropyl methylcellulose (HPMC) at various concentrations (Table 1) was used as binder and 12.5% w/w WMP or corn starch BP (control) was incorporated intragranularly. One hundred grams (100 g) batches of a basic formulation of ibuprofen powder (44.44% w/w), corn starch BP or WMP as disintegrant (12.50% w/w) and lactose as filler were dried mixed for 10 min in a planetary mixer (Model A 120, Hobart Manufacturing CO, UK). The powder mixture was moistened with the appropriate amount of starch paste, PVP or HPMC solution in water and granulated by wet massing with mortar and pestle. The homogeneous wet mass was then screened through a 1000 µm sieve and the wet granules dried in a hot air oven (Unitemp LTE Scientific Ltd Great Britain) at 50°C for 1 h. Thereafter, the dried granules were screened through a 600 µm sieve, dried again at 50oC for 1 h and stored in air tight containers over silica gel.

Table 1: Formula for the preparation of ibuprofen granules

Ingredients	Amount
New polymer or corn starch paste as binder	
Ibuprofen	200 mg
WMP or corn starch BP	2.5, 5.0, 7.5, 10.0% w/w
Corn starch BP	12.5% w/w
Lactose	qs 450 mg
*Magnesium strearate	0.5% w/w
New polymer or corn starch powder as disintegrant	
Ibuprofen	200 mg
PVP or HPMC	2.0, 3.0, 4.0% w/w
WMP or Corn starch BP	12.5% w/w
Lactose	qs 450 mg
*Magnesium strearate	0.5% w/w

*Amount is with respect to the final weight of granules

Evaluation of Some Micromeritic Properties of Granules

Particle Size Analysis of Granules

Analytical sieving method was used and each sieve was tarred to the nearest 0.001 g. Thereafter, 40 g of the granules was carefully loaded on the coarsest sieve of the assembled stack (1000□m to 150□m) and the lid was replaced. The nest was subjected to mechanical vibration using the Shaker (AS 400 Retsch, Germany) for 25 min at 5 min interval per shaking session. Thereafter, the sieves were carefully separated and each sieve was carefully reweighed with its content. The weights of powder retained on each sieve and the collecting pan were determined by difference. The values were used to calculate the percent of sample retained on each sieve and the average diameter of the granules (dav) was evaluated using the formula [13]:

$$d_{av} = \frac{\sum (\% \text{ retained x mean aperture size})}{100} \quad ...(1)$$

Determination of Derived Properties of the Granules

The particle density, bulk and tapped densities, Carr's index, Hausner's ratio, angle of repose and flow rate were conducted using established protocols [14-15].

Compaction of Granules into Tablets

Prior to compaction, each batch of granules was lubricated with 0.5% w/w magnesium stearate. Granules compaction was conducted using a 12 station rotary tableting machine (JC – RT - 24H, Jenn Chiang Machinery Co., LTD, Feng – Yuan, Taiwan) with die depth preset to contain 450 mg of granules and fitted with 13 mm flat faced punches. The compaction pressure was 12.5 KN and the resulting tablets were stored in airtight containers for 72 h before their qualities were evaluated.

Evaluation of Tablet Properties

Tablet Weight Variation

The individual weights of twenty tablets selected at random from each batch were determined using an analytical balance (Mettler Toledo AB54 GmbH USA). The percentage deviation of each tablet from the mean was evaluated and assessed in accordance to official requirements [16].

Crushing Strength, Friability and Disintegration Tests

Tablets crushing strengths were evaluated on twenty tablets selected randomly from each batch using a hardness tester (Kal Kolb, Erweka Germany). Ten tablets were used for friability test (Roche friabilator, Copley/Erweka, Type, TAR 20, GMBH Germany); while six were used for disintegration tests (Manesty, Model: MK 4, UK). The tests were conducted as prescribed in the British Pharmacopoeia [16].

Dissolution Test

The BP basket method was employed using a dissolution test machine (Erweka Germany Type: DT 80) operated at 50 rpm for 60 min in 900 ml of phosphate buffer, pH 7.2, and maintained at 37 ± 0.5oC. One tablet selected at random from each batch was used in each run and 5 ml of dissolution fluid was withdrawn from the dissolution chamber and replaced with 5 ml of fresh medium at the following intervals: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 min. Each withdrawn sample was filtered and its absorbance determined with a UV – Visible spectrophotometer (UV– 160A Shimadzu Corporation Japan) at 240 nm using phosphate buffer, pH 7.2, as blank. Triplicate determinations were made for each batch and the mean used to evaluate the amount of drug released by applying the calibration curve equation: $y = 0.003x + 0.0026$; $r2 = 0.987$.

Statistical Analysis

The results of the experiment were analyzed with regression analysis (Excel 2007) and one way ANOVA (Excel 2007) with the null hypothesis that there is no significant difference between the pharmaceutical properties of tablets formulated with WMP and those formulated with corn starch BP as binders or disintegrants.

Results and Discussion

Physicochemical and Phytochemical Characteristics of the Polymer

The polymer extracted was pale grey in colour and constituted 18.31± 0.57% of the dehulled seeds on dry weight basis. Phytochemical analysis suggested that it contains only/ predominantly protein since other constituents tested for including cellulose were absent (Table 2). Initially this polymer was arbitrarily suspected to be starch or cellulose, but upon analysis, it turned out to be neither. Although no report of starch extraction from watermelon seeds has been made, some authors have reported the presence of carbohydrate [5, 17]. The present finding might be accounted for by the extraction and purification processes employed which cleared off the presumably water soluble carbohydrates leaving the protein rich polymer. Furthermore, notwithstanding the ubiquitous nature of cellulose in plants, hydrolysis of the polymer and test for sugars gave negative results for cellulose. This is instructive and points to the fact that the polymer is unique, being a non carbohydrate polymer.

The total ash value for the polymer is 0.98±0.17% (Table 2). Total ash value includes physiological ash, which is derived from the plant tissues and non-physiological ash which is often from environmental contaminations [18]. The low value indicated low level of contamination with inorganic compounds, including heavy metals. The contents of heavy metals in the polymer was evaluated from their calibration curves (Fig.3) and were found to be below the acceptable limits [19-20], with some being entirely absent (Table 2). Selenium and cobalt are generally portrayed as being medicinal, but however belong to class 2A (toxicity depends on route of intake but contamination level must be determined due to their higher relative natural abundance) under ICH guidelines [21].

The mean values of pH, particle density, swelling index (SI) and loss on drying of the polymer are 6.66±0.07, 1.70±0.06 g/ml, 50.67±1.15% and 9.67±0.19% respectively (Table 2). The polymer is therefore very slightly acidic; swells more than corn starch BP (SI = 12.77±2.01%) and microcrystalline cellulose (SI = 41.40±1.70%). This high swelling index may be beneficial in the formulation of tablets where the polymer could function as a disintegrant

FTIR Spectroscopy of the New Polymer

The FTIR spectrum of the new polymer is shown in Figure 1. The peaks within the range 3130 cm-1 to 3821 cm-1 are characteristic of the following functional groups: — OH stretching from water molecules, — NH stretching from amide group in protein and /or probably an aromatic — CH stretching. The broad peaks between 2536 cm^{-1} and 2987 cm^{-1} may be ascribed to — OH stretching of carboxylic acid group. The multiband in this range also suggests that C—H stretching may be present [22-23]. The strong peaks between 1636 cm^{-1} and 1862 cm^{-1} are indicative of C=O stretching from probably amide, aldehyde, ester, ketone or carboxylic acid group. However, because of the lower frequency, it is most likely from an amide group [24].

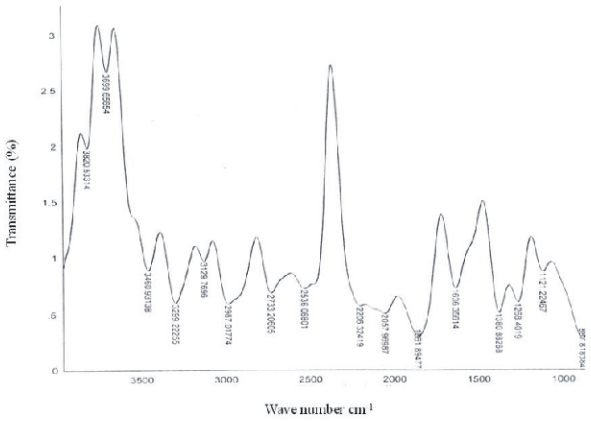


Figure1: FTIR spectrum of the new polymer

There is also the likelihood of C=C from either an alkene or an aromatic ring [24]. The peaks between 1121 cm^{-1} and 1380 cm^{-1} suggest the presence of Ar —O or C—O stretching from an alcohol group or C— N stretching from an amine group [23]. The peaks between 644 cm-1 and 888 cm^{-1} suggest the presence of C—H out-of-plane bend present in a phenyl group [24]. These functional groups depicted portray the information that the new polymer is most probably composed of protein; and this is corroborated by the results of phytochemical analysis of the new polymer (Table 2). The calibration curves for the determination of heavy metal contents are given in Figure 2.

Table 2: Physicochemical and phytochemical characteristics of the new polymer

Phytochemicals	Presence	Physical property	Value	Heavy metal	Mean Absorbance	Content (ppm)
Cellulose	-	pH	6.66±0.07	Mercury	0.0017	0.452
Starch	-	Ash (%)	0.98±0.17	Cadmium	0.0052	0.157
Reducing sugars	-	LOD (%)	9.67±0.19	Arsenic	0.0006	0.008
Alkaloids	-	PD (g/ml)	1.70±0.06	Lead	0.0045	0.501
Tannins	-	SI (%)	50.67±1.15	Cobalt	0.0040	0.258
Flavonoids	-			Selenium	-0.0005	0.000
Saponins	-			Chromium	-0.0005	0.000
Steroids	-					
Cardiac glycosides	-					
Terpenoids	-					
Protein	+					

LOD: loss on drying; PD: particle density; SI: swelling index

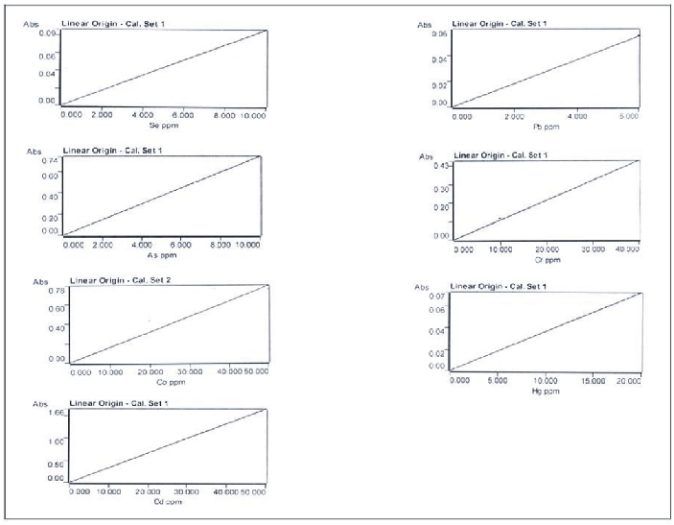


Figure 2: Calibration curves for the evaluation of heavy metal contents

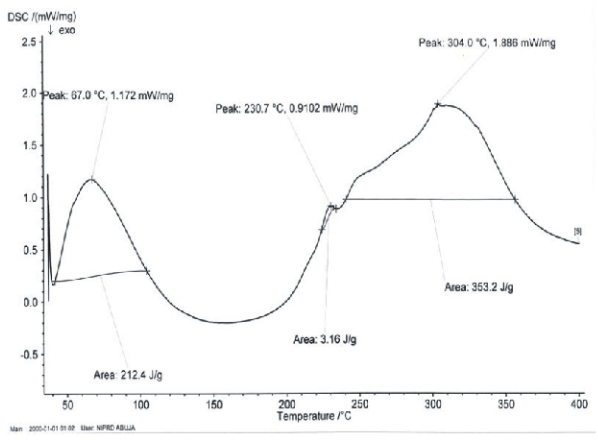


Figure 3: DSC thermogram of the new polymer

DSC Thermogram of the New Polymer

The first endothermic event in the thermogram of the new polymer is indicative of desorption temperature which is about 67°C (Figure 3). The vapour escaping from the polymer at this temperature may be water vapour or hydroalcoholic vapour which might have emanated from the deeper parts of the particles. A melting peak appeared at about 230.7°C and was immediately followed by decomposition which peaked at about 304oC. The endothermic event at 230.7°C is not a sharp one, which suggests that the polymer is not crystalline in nature.

Micromeritics of Ibuprofen Granules

The mean particle diameter of the granules ranged from 232 μm (IBU: granules of API without excipients) to 311 μm (CS 10.0 and PVP-3DW) as shown in Table 3 and Table 4. The lowest mean particle diameter of IBU was expected because in the absence of binder(s) the bonding between particles was so loose that ordinary screening through the sieve disrupted the granules structures leading to the formation of smaller particle agglomerates. Among the granules formulated with binders, there was no trend in mean particle diameter differences. This implies that all the binders used, including WMP, imparted strong bonding between particles thereby successfully prevented extensive disruption of granule structures during screening and particle size analysis operations. The similarity in mean particle diameters and particle size distribution (not shown) was also reflected in the flow properties. Except IBU, all the other granules displayed excellent flow properties with respect to angle of repose scale. When graded using Carr's index and Hausner's ratio scales, they fall within the fair flow characteristics [25]. It is however important to state that the angles of repose of granules formulated with WMP as binder at concentrations of 2.5–7.5% w/w were significantly higher ($p<0.05$) than those of other granules. There was however no significant difference between the flow rate of all the granules as evaluated using flow through the orifice of a funnel.

Table 3: Micromeritic properties of ibuprofen granules containing new polymer or corn starch paste as binder

Batch/ Binder (% w/w)	d_{av} (μm)	Bulk density (g/ml)	Tapped density (g/ml)	Carr's index (%)	Hausner ratio	Angle of repose (°C)	Flow rate (g/sec)
IBU*	232	0.48±0.03	0.71±0.04	32.39	1.47	36.13±4.13	2.86±0.43
WMP 2.5	288	0.51±0.02	0.67±0.03	23.88	1.31	29.67±3.06	3.73±0.31
CS 2.5	293	0.50±0.02	0.65±0.05	23.08	1.30	22.33±2.08	3.97±0.15
WMP 5.0	296	0.51±0.03	0.68±0.05	25.00	1.33	29.00±5.57	4.10±0.17
CS 5.0	299	0.52±0.02	0.65±0.03	20.00	1.25	23.33±1.15	4.07±0.31
WMP 7.5	290	0.52±0.01	0.69±0.04	24.64	1.33	28.33±1.53	4.17±0.15
CS 7.5	301	0.51±0.02	0.69±0.03	26.09	1.35	21.00±2.65	4.63±0.25
WMP 10.0	295	0.52±0.03	0.68±0.04	23.53	1.31	21.67±1.53	4.20±0.26
CS 10.0	311	0.52±0.02	0.69±0.03	24.64	1.33	23.00±2.65	4.43±0.35

**ibuprofen granules with no excipient*

Table 4: Micromeritic properties of ibuprofen granules containing new polymer or corn starch as disintegrant

Batch/ Binder (% w/w)	d_{av} (μm)	Bulk density (g/ml)	Tapped density (g/ml)	Carr's index (%)	Hausner ratio	Angle of repose (°C)	Flow rate (g/sec)
PVP-2 DW	296	0.50±0.03	0.69±0.03	31.66	1.38	22.67±1.53	4.33±0.31
PVP-2 DC	299	0.57±0.02	0.70±0.04	18.57	1.23	19.67±2.08	4.43±0.06
HPMC2DW	308	0.55±0.03	0.73±0.03	24.66	1.33	22.33±3.21	4.40±0.20
HPMC2 DC	305	0.57±0.04	0.74±0.04	23.00	1.30	23.67±3.51	4.27±0.25
PVP-3 DW	311	0.55±0.05	0.69±0.04	20.28	1.25	20.33±0.58	4.47±0.23
PVP-3 DC	304	0.55±0.04	0.67±0.03	17.91	1.22	17.33±2.52	4.73±0.12
HPMC3DW	306	0.57±0.05	0.69±0.03	17.39	1.21	18.00±2.00	4.57±0.15
HPMC3 DC	299	0.56±0.03	0.70±0.02	20.00	1.25	20.33±1.53	4.73±0.12
PVP-4 DW	302	0.53±0.03	0.68±0.04	22.06	1.28	25.00±2.65	4.70±0.10
PVP-4 DC	307	0.51±0.03	0.69±0.04	26.09	1.35	20.67±1.15	4.63±0.15
HPMC4DW	296	0.53±0.03	0.71±0.03	25.35	1.34	18.67±0.58	4.23±0.15
HPMC4 DC	303	0.52±0.03	0.71±0.03	26.76	1.37	18.33±1.53	4.27±0.31

Mechanical Properties of Tablets

It can be observed from Table 5 that except tablets containing no excipients (IBU), all others met the requirement for weight uniformity [16]. This is a reflection of the good flow properties of the granules, because granule good and uniform flow ensures that equal volumes are injected into the dies before compression by the punches. The poor flow properties of IBU granules therefore, might very likely be responsible for its failure of weight uniformity test.

Tablet hardness values for all the formulations (Table 5) were higher than the accepted minimum (4 Kg) [25], implying that the new polymer was able to cause adequate bonding between the various powder particles thereby enabling them to resist to a high degree diametrical compressive force responsible for tensile failure during tablet hardness test. All tablets friability results, except IBU were less than 1.0% which is the official maximum acceptable value [25]. Tablet hardness and friability are indices of a binder's ability to forestall tablet's tendency to break or wear during handling, packaging and transportation. That WMP possesses this ability in comparison to other well established binders is noteworthy and suggests that it could be a suitable excipient for the manufacture of tablets.

Tablet disintegration time, a pointer to a formulation's ability to release its drug content revealed that with the exception of formulations containing HPMC or PVP 4% with WMP as disintegrant, other batches met the 15 min maximum for disintegration of conventional tablets [26]. It is obvious from the results (Table 5) that WMP is not as good a disintegrant as corn starch BP even though it possesses higher swell index. This is very obvious at higher binder concentration, for instance for PVP at 3 and 4% w/w, in which a significant difference ($p < 0.05$) was revealed between the time of disintegration of tablets containing WMP as disintegrant and those containing corn starch BP.

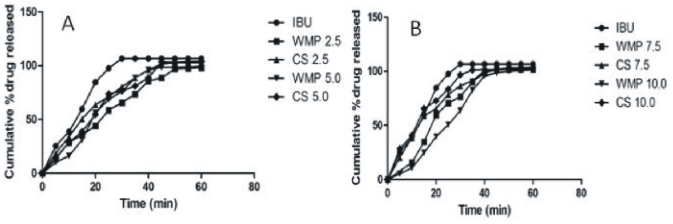
Table 5: Mechanical properties of ibuprofen tablets

Batch/ Binder (% w/w)	Weight uniformitya	Tablet Hardness (Kg)	Friability (%)	Disintegration Time (min)
IBU*	5	5.67±0.33	6.84	7.42±0.13
WMP 2.5	0	7.40 ± 0.99	0.99	0.57 ± 0.27
CS 2.5	1	7.45 ± 1.15	0.85	0.24 ± 0.07
WMP 5.0	1	7.65 ± 0.99	0.82	0.22 ± 0.06
CS 5.0	0	7.90 ± 1.33	0.88	0.24 ± 0.06
WMP 7.5	0	7.90 ± 1.17	0.73	0.45 ± 0.07
CS 7.5	0	8.00 ± 1.30	0.45	0.36 ± 0.06
WMP 10.0	0	8.65 ± 1.14	0.41	0.45 ± 0.23
CS 10.0	0	8.80 ± 1.01	0.32	0.55 ± 0.19
PVP-2 DW	0	6.20 ± 0.89	0.20	3.78±0.53
PVP-2 DC	0	7.25 ± 0.91	0.40	2.64±0.28
HPMC-2 DW	0	6.45 ± 1.05	0.18	23.53±0.35
HPMC-2 DC	0	6.55 ± 0.89	0.33	17.23 ± 0.09
PVP-3 DW	0	7.25± 0.97	0.27	7.80 ± 0.09
PVP-3 DC	2	7.70±0.86	0.31	5.43±0.32
HPMC-3 DW	1	7.45±1.05	0.36	77.50 ± 9.59
HPMC-3 DC	0	7.70±0.99	0.32	87.12±6.73
PVP-4 DW	0	7.45±1.00	0.34	23.42±1.36
PVP-4 DC	1	8.30±0.73	0.38	12.66±2.54
HPMC-4 DW	0	7.65±0.75	0.43	107.17 ± 6.31
HPMC-4 DC	0	7.70±0.92	0.56	108.83 ± 5.64

*[a]: number of tablets with % deviation > 5.0%; *: ibuprofen tablet with no excipient*

Dissolution Profile of Tablets

The dissolution profiles of ibuprofen tablets studied are shown in Figure 4. The cumulative percent drug released over 60 min by tablets formulated with WMP paste as binder was greater than 95% in all cases. The t90% values of the tablets (time to release 90% of drug) was less than 40 min except for WMP 2.5 batch. The amount of drug released increased as WMP paste concentration increased; and this may be attributed to the swelling characteristics of the polymer. It swells without forming a gel and this may further explain the trend since exit of dissolved drug from the granules is enhanced by the imbibitions of dissolution medium. Tablets formulated with corn starch BP paste displayed similar profiles with WMP batches. On statistical analysis of cumulative amount of drug released at 15, 30, 45 and 60 min, it was revealed that tablets formulated with corn starch BP paste released significantly higher ($p < 0.05$) amount of drug at 15 and 30 min but not at 45 and 60 min, although this is not obvious from Figure 4A-C.



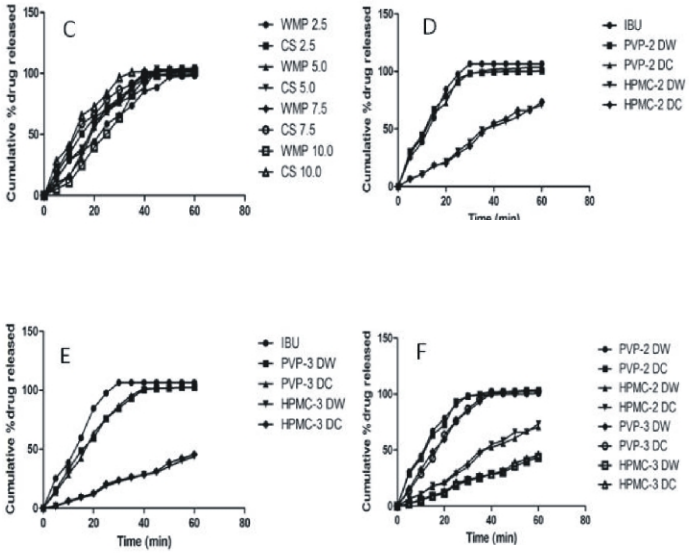


Figure 4: Dissolution profile of ibuprofen tablets formulated with the new polymer and other standard excipients as binders/disintegrants

The profiles of tablets formulated with PVP or HPMC as binder and WMP or corn starch BP as disintegrant are depicted in Figure 4D–F. Generally HPMC containing tablets released poorly irrespective of disintegrant type. This may be explained by the gel forming nature of HPMC as it imbibes dissolution medium and swells, thereby entrapping the dissolved drug, an effect that has been reported previously [27]. Although the disintegration time test projected corn starch BP as a better disintegrant, this superior property did not reflect in the dissolution profile of the formulations, where significant difference in the amount of drug released over time was not revealed. Invariably, the release profiles of tablets containing WMP as disintegrant were comparable to those containing the standard disintegrant, corn starch BP.

Conclusion

The new polymer from watermelon seed is most likely an amorphous substance and is highly suspected to be a protein. It is slightly acidic and swells about five times more than corn starch BP. This study has been able to reveal that it can function comparatively excellently as tablet binder and disintegrant in conventional tablet dosage forms.

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Conflict of interest

The authors declare no conflict of interest

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