# Evaluation of Musa Paradisiaca (Banana Peel) Pectin as A Pharmaceutical Excipient in Ciprofloxacin Tablet Formulation

**Obarisiagbon[1]* Aiwaguore Johnbull, Airemwen[2], Collins Ovenseri And Obianuju[1] Jennifer Chude**

[1]Department of Pharmaceutics and Pharmaceutical Technology, College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria.
[2]Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmacy, University of Benin, Benin City, Edo State, Nigeria

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***Abstract***- This study aimed at evaluating *Musa paradisiaca* (banana peel) pectin as a pharmaceutical excipients (binder) in ciprofloxacin tablet formulation. The banana peel pectin was extracted from the peel of *Musa paradisiaca* (banana). The granules formulated were evaluated for micromeritic properties. The granules were then compressed to tablets at a compression pressure of 30N/m$^2$. The resulting ciprofloxacin tablets were evaluated for hardness, friability and disintegration time, in vitro dissolution studies and release kinetics. The extracted banana peel pectin was found to contain the following phytochemicals – flavonoids, tannins, carbohydrates, reducing sugar, saponins, alkaloids, phytosteroids and glycosides. However, steroids, anthraquinones, phenols and terpenoids were absent. The different batches of formulated granules were free flowing with angle of repose between 17.21 $\pm$ 0.20 to 23.45 $\pm$ 3.50; bulk density (0.39 $\pm$ 0.03 to 0.48 $\pm$ 0.04); tapped density (0.05 $\pm$ 0.04 to 0.52 $\pm$ 0.01); compressibility index (8.15 $\pm$ 3.10 to 13.46 $\pm$ 1.80); Hausner's ratio (1.09 $\pm$ 0.03 to 1.16 $\pm$ 0.03) and flow rate (0.27 $\pm$ 0.07 to 0.59 $\pm$ 0.29). All formulated ciprofloxacin tablets were uniform in weight. Their hardness were satisfactory (4.01 $\pm$ 0.07 to 6.54 $\pm$ 1.02 kg/cm$^2$); friability values ranging from 0.67 to 1.10% with tablets formulated with banana peel pectin being less friable. The tablets disintegrated within 15 min except those formulated with 10% w/v binder – Acacia 10% w/v (18.40 $\pm$ 0.26), PVP 10% w/v (16.20 $\pm$ 0.20) and banana peel pectin 10% w/v (18.20 $\pm$ 0.50), minutes respectively. Increase in the binder concentration resulted in a corresponding increase in hardness and disintegration time but decrease in percentage friability. All batches fitted into the Higuchi model release kinetics. Banana peel pectin exhibited good binding property comparable to those of the standard Acacia BP and polyvinylpyvrodone BP powders.

***Index Terms***- Banana, Pectin, Ciprofloxacin, Tablets, Acacia, Polyvinylpyrrolidone.

## I. INTRODUCTION

Mother Nature has presented to mankind underutilized gift of a broad range of materials to help improve and preserve the health of all living things either directly or indirectly. Today, the whole world is increasingly paying attention to natural drugs and excipients derived from natural sources. In recent years, plant derived polymers have evoked tremendous interest due to their diverse pharmaceutical applications such as diluent, binder, disintegrant in solid oral dosage forms; thickness in oral liquid preparations; protective colloids in suspensions and bases in suppository, etc. They have also been found useful in cosmetics, textiles, paints and paper making (Deogade *et al*., 2012). Many pharmaceutical excipients of plant origin, like starch, agar, gums, gelatin, pectin, flavouring and sweetening agents are widely applied within the pharmaceutical industry (Singh *et al*., 2016). Some specific applications of plant-derived polymers in pharmaceutical formulations include their use in the manufacturing of implants, films, beads, micro and nano-particles inhalables and injectable systems as well as viscous liquid formulations (Pandey, 2004; Alonso-Sande, 2009).

The predictable use of excipients in drug formulations was to act as inert vehicles to provide the required weight, consistency and volume for the correct administration of the active ingredient, but in modern pharmaceutical dosage forms, they often fulfill multifunctional roles such as modifying release, enhancement of the stability and bioavailability of the active ingredients. They also enhance patient acceptability and ensure simplicity of manufacture (Bharat, *et al*., 2013). Pectins are a class of complex polysaccharides found in cell walls of higher plants where they function as a hydrating agents and cementing material for the cellulosic network (Muralikrishna *et al*., 1994). Pectin is one of the main structural components of plant cell walls, commonly produced. This polysaccharide is composed of a backbone of (1 $\rightarrow$ 4) – linked $\alpha$-D-galactinronic acid units. The "smooth" homogalacturonic regions are interrupted by "hairy" rhamnogalacturonic regions where galacturonic acid units are interspersed with (1 $\rightarrow$2) – linked $\alpha$-L-rhamnopyranosil residues. Rhamnosyl units can be substituted by side chains containing, arabinose and galactose. Galacturonic acid residues can be partially esterified by methanol on the carboxyl group and by acetyl on the secondary hydroxyls. Rhanogalacturonan II contains erabinan, galactan and arabinogalactan side chains. These monosaccharide units comprise most of sugar units found in pectin. Pectins have been used in food industry, but is recently being explored for their other pharmaceutical applications such as binding, thickening, and suspending properties (Willats *et al*., 2006).

Bananas are one of the most important food crops, with a global annual production that surpassed 100 million tons in 2011

(The World Banana Forum, 2014). Bananas are mostly consumed raw, and their processed products include banana flour, chips, and puree (which can be used to produce nectars, smoothies, and a variety of other products). Banana peels constitute about 30% of the fruit and represent an environmental problem because of their large nitrogen and phosphorus contents as well as their high water content, making them highly susceptible to microbial degradation (Gonzalez-Montelongo *et al*., 2010).

The use of banana peels as a source of high value compounds such as pectin (Emaga *et al*., 2008), cellulose nanofibers (Tibolla *et al*., 2014) and phenolic compounds (Gonzalez-Montelongo *et al*., 2010; Rebello *et al*., 2014) is interesting not only from an economic point of view, but also from an environmental perspective. Experimental research conducted by Bansal *et al*., 2014, concluded that natural polymer derived banana pectin can be used as a pharmaceutical excipient for oral drug delivery and has sufficient potential to be used as pharmaceutical excipient in matrix tablets forming system with lactose, polyvinyl pyrolidone and talc.

The past 25 years had witnessed a high influx of antimicrobial agents being introduced at a rate exceeding our ability to integrate them into clinical practice. Among these, fluoroquinolones have become a mainstay in the treatment of serious bacterial infections (Buck, 1998). These are synthetic antibacterial agents structurally related to nalidixic acid (Pandey, 2003). They depict several favourable properties such as excellent bioavailability, good tissue penetrability, and relatively low incidence of adverse and toxic effects. One of the most successful and widely used compounds of the class, ciprofloxacin, was patented in 1983 by Bayer A.G. (Appelbaum *et al*., 2006).

Ciprofloxacin is marketed worldwide, with well over 300 different brand names, and since its introduction, the value of fluoroquinolones for the respective uses has been recognized. Ciprofloxacin may interact with several other drugs, some herbal and natural supplements, and certain thyroid medications (Cooper *et al*., 2005).

Banana peel is generally discarded as a waste; however, it is a very rich source of important phyto-constituents. The peel contains 6-9% dry matter of protein and 20–30% fibre. Usually the ripe banana peels contain 30% free sugar and 15% more starch than the green banana peels. Moreover, banana peel is a good source of lignin, cellulose, and hemicellulose with variety of active functional groups (carboxyl, hydroxyl, and amine) (Deshmukh *et al*., 2017; Mondal *et al*., 2018). According to Bharathi *et al*., 2017, the phytochemical analysis of *Musa paradisiaca* and *Musa acuminate* peels revealed the presence of phenols, carbohydrates, terpenoids, and saponins. The presence of such potent phyto-constituents in banana makes it a great target for nutritional and therapeutic researches.

The structure of pectin is very difficult to determine because it can change during isolation from plants, storage, and processing of plant material. At present, pectin is thought to consist mainly of D-galacturonic acid (Gal A) units joined in chains by means of a – (1- 4) glycosidic linkage. These uronic acids have carboxyl groups, some of which are naturally present as qq methyl esters and others which are commercially treated with ammonia to produce carboxamide groups (Muralikrishna G et al., 1994).

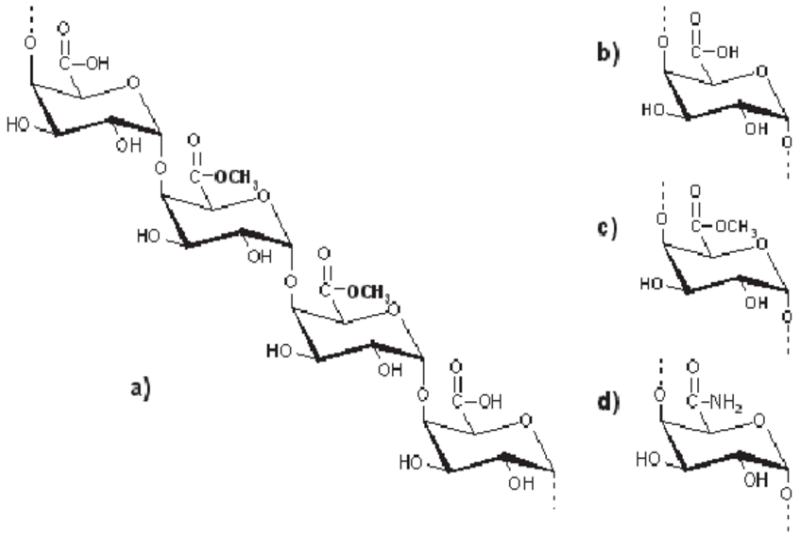


**Figure 1. (a) Repeating segment of pectin molecule and functional groups; (b) carboxyl; (c) ester (d) amide in pectin chain.**

Pectin hydrogels have been used in tablet formulations as a binding agent and as controlled-release matrix tablet formulations. The application of a binary polymer system, i.e. HM-pectin and hydroxypropyl methylcellulose in drug release rate modulation for oral administration was also studied by Kim *et al*., 1997. This study hopes to ascertain the validity of *Musa paradisiaca* (banana peel) pectin as a binder in ciprofloxacin tablet dosage form. The physicochemical properties of the granules and tablets are being compared with those formulated using polyvinyl pyrrolidone and acacia gum as binder respectively.

## II. MATERIALS AND METHOD

### Materials and chemical

Unripe banana (*Musa paradisiaca*) was purchased from a local market at Oakda town, Ovia North-east, Edo State, Nigeria. Pure ciprofloxacin powder (CDH Vardaan Daryaganj, New Delhi, India) was supplied by a chemical vendor, in Benin City, Edo State. Other excipients: Anhydrous lactose BP powder (Danone® Germany), Acacia gum BP (CDH Vardaan, Daryaganj, New Delhi), Maize starch BP powder, polyvinyl pyrrolidone (CDH Vardaan, Daryaganj, New Delhi, India) were all supplied by Sonitex (Nig) Ltd, Benin City, Edo State, Nigeria. The reagents, Ethanol 97% and Hydrochloric acid both Analar® BDH Limited Poole, England, were purchased from Sonitex (Nig) Limited, Benin City.

**Preparation of sample solution**

The sample was prepared in accordance with the method adopted by Kulkarni S.G. and Vijayanand (2010). The extraction method using hydrochloric acid was used. Hydrochloric acid (50%) was diluted to various pH of 1.0, 1.5, 2.0, and 2.5 and measured using a pH meter (Mettler, Toledo, Malaysia).

**Preparation of the sample for pectin extraction**

The banana were carefully washed and hand peeled and separated from its flesh. The banana peels (500 gm) were weighed and then blanched in boiling distilled water at 100$^{o}$C for 5 min. The peels was allowed to cool to room temperature, chopped into pieces, and packed in sealed low-density Polyethylene (LDPE) bags and stored in the freezer at -20$^{o}$C until being used for extraction.

**The extraction of pectin**

The extraction process was based on the method of Kulkarni SG and Vijayanand (2010) with some modifications. The frozen banana peels were thawed prior to mixing with 0.05M HCl at a ratio 1:2 (w/v). The pH of the resultant mixture was adjusted to 1.5 to prepare acid-extracted banana peel pectin. The extraction was performed at 90 $\pm$ 5$^{o}$C with agitation on a hot plate for 60 min. The mixture was then filtered through double-layer nylon cloth. The filtrate was mixed with 95% ethanol at a filtrate-to-ethanol volume ratio of 1:2 and left undisturbed at room temperature for 12 hours. The precipitated pectin was harvested, washed twice with 95% ethanol at a volume ratio of 1:1 dried at 50$^{o}$C in hot air oven until dry (< 10% moisture). The dried precipitate was ground, packed in sealed LDPE bags and kept in the desiccator until usage.

(a) (b) (c)

Figure 2 (a) unripe banana bunches. (b) extracted banana peel pectin (c) dry banana peel pectin.

**Determination of percentage yield**

The banana peel pectin obtained from the extraction was calculated on a dry weight basis using the equation (Castillo-Israel *et al*., 2015):

$$\% \text{ Pectin Yield} = \frac{\text{Weight of extracted dried pectin (gm.)}}{\text{Weight of sample (gm)}} \times \frac{100}{1} \quad \text{--------- 1}$$

**Organoleptic properties of the extracted pectin**

The colour, taste and odour of the banana peel pectin were carefully examined and results of observations recorded.

**Phytochemical screening of banana peel pectin**

Standard phytochemical screening was carried out to test for the presence of components such as saponins, tannin, flavonoid, alkaloids, cardiac glycosides, steroids, terpenoids and anthraquinones.

**Preparation and formulation of ciprofloxacin granules**

**Table 1: Formula for ciprofloxacin granules**

| Binder Conc | 2.5 %w/v | 5 %w/v | 7.5% w/v | 10% w/v |
|---|---|---|---|---|
| Ciprofloxacin (mg) | 500 | 500 | 500 | 500 |
| Distintegrant (5% w/w) mg | 30 | 30 | 30 | 30 |
| Diluent (mg) | 50 | 50 | 50 | 50 |

| | | | | |
|---|---|---|---|---|
| Binder (BPP/ Acacia/PVP) at @ 2.5, 5.0, 7.5 & 10% w/v used to wet granulate | | | | |
| Total weight (mg) | 580 | 580 | 580 | 580 |

The powder mass was wet granulated using the various binder types and concentrations to produce 12 different batches of ciprofloxacin granules. The wet mass was sieved by forcing it through a sieve of aperture size 5 BSS and spread on trays and dried in the oven at 50ºC for 1 hour. The dried granules were sieved using a sieve of aperture size 10 BSS and packed in airtight containers and stored in a desiccator for further analysis and compression into tablets using Single punch tableting machine (Manesty, England).

**Physicochemical properties of ciprofloxacin granules:**

**Flow properties of granules**

***Angle of repose:*** This was determined by allowing the granules to flow through a funnel (size) and fall freely onto a surface. Further addition of granules was stopped as soon as the pile touched the tip of the funnel. The height and diameter of the resulting cone were measured. The procedure was repeated thrice for each batch and average value of each calculated and recorded. The angle of repose was calculated using the equation:

$$\tan \theta = {}^{h}/_{r} \quad \text{---------- (2)}$$

Where h = height of the granule cone; and r = radius of the cone

***Bulk density:*** Granules (100 mg) was screened through a 1 mm (no 18) screen to break up agglomerates that may have been formed during storage and poured into a dry 250 ml measuring glass cylinder. The cylinder was filled carefully without compacting. The apparent volume ($V_o$) was read and noted. Bulk density was calculated in g/ml using the formula:

$$\text{Bulk density} = {}^{M}/_{Vo} \quad \text{---------- (3)}$$

Where M = the mass (gm) of the granules

***Tapped density:*** The granules (100 g) was introduced into a measuring glass cylinder and then tapped by raising the cylinder and allowing to drop below its own weight. The cylinder was tapped 50 times and the tapped volume ($v_t$) was measured.

$$\text{Tapped density} = {}^{M}/_{v_t} \quad \text{---------- (4)}$$

Where M = weight of the granules sample (gm); $v_t$ = tapped volume

***Carr's index***: The compressibility index of the granules was determined using Carr's compressibility index as follows:

$$\text{Carr's index} = \frac{\text{Tapped density} - \text{Bulk density}}{\text{Tapped density}} \times \frac{100}{1} \quad \text{---------- (5)}$$

***Hausner's ratio*****:** The Hausner's ratio of the granules was determined using the following formula:

$$\text{Hausner's ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad \text{---------- (6)}$$

**Compression of ciprofloxacin granules:** The granules were blended with a lubricant (1% w/w) in a tumbling mixer for 5 minutes. The blend was compressed into tablets of 580 $\pm$ 5 mg using Manesty Single Punch Machine at 30 $N/m^3$ compression force. The compressed ciprofloxacin tablets were dusted and stored in airtight containers which were pre-labelled accordingly.

**Figure 3. Samples of compressed ciprofloxacin tablets with banana peel pectin as binder**

**Evaluation of the physicochemical properties of ciprofloxacin tablets:**

***Hardness test:*** The tablet hardness was determined by diametrical compression using the Campbell Electronics Hardness tester machine (HT30/50). The pressure required to fracture a tablet placed in the anvil of the hardness tester was determined. From each

batch, five (5) tablets were randomly selected and subjected to the test. The mean value (kgf) of these five tablets was calculated and recorded.

***Friability test:*** The friability was determined using Roche Friabilator (Erweka Germany). Ten tablets were randomly selected, dusted and weighed ($W_1$ gm). They were then placed in the frabilator and allowed to make 100 revolutions at 25 rpm. The tablets were again dusted, reweighed ($W_2$ gm) and the percentage weight loss calculated.

$$\text{Friability (\%)} = \frac{W_1 - W_2}{W_1} x \frac{100}{1} \quad \text{---------- (7)}$$

***Weight Variation*:** The weight variation of the tablets was determined using both the British Pharmacopoeia (BP) and the United State Pharmacopoeia (USP) recommended method of weighing 20 tablets individually and taking the mean. This determination was repeated for all the different formulations and mean weight recorded.

**Disintegration test:** The disintegration time was determined using a disintegration test apparatus. The apparatus consists of six separate tubes, each with an open end at the top and held against a 10-mesh screen at the bottom end of the basket rack assembly. To test the disintegration time, the basket rack was positioned in a 1 litre beaker containing 800 ml of distilled water maintained at a temperature of 37ºC ± 2ºC. A tablet was placed in each tube, and the basket assemblage was moved up and down through a distance of 5–6 cm at a frequency of about 30 cycles per minute until the tablet broke down into smaller particles which pass through the mesh. The time taken was recorded and triplicate determinations were done and the mean time recorded.

**Binder efficiency:** The binder efficiency of the tablets was evaluated using tablet hardness, friability and disintegration time values. The crushing strength (Cs) – Friability (Fr) ratio is given as

$$\text{CsFr} = \frac{\text{Crushing strength (N)}}{\text{Friability (\%)}}$$

$$\text{Binder efficiency} = \frac{\text{Tablet hardness (Cs)}}{\text{Friability (Fr)}} x \frac{1}{D_t} \quad \text{---------- (8)}$$

Where $D_t$ = disintegration time (min)

Correlations between CsFr and $D_t$ for the tablet formulations were determined by ANOVA and linear regression tests at $p = 0.05$, using the statistical software.

***In-vitro* dissolution studies:** The dissolution tests were performed in triplicates using a dissolution apparatus (paddle): (ST7, GB Calera ltd, England). The USP dissolution apparatus contained 800 ml distilled water maintained at a temperature of 37ºC ± 0.5ºC with the aid of a thermostatic control and a stirrer, and kept in an outer water glass container with a heating device. The motor was set to rotate at a speed of 120 rpm. With the aid of a 5 ml pipette, samples (5 ml) of the dissolution medium were withdrawn at every time interval of 15 min for 90 min. An equal volume of fresh medium (distilled water) at the same temperature with the dissolution medium was replaced each time withdrawal was made. The samples were filtered and suitably diluted. UV-Spectrophotomer was used to determine their absorbances at maximum wavelength, λmax = 278 nm.

## III. RESULTS AND DISCUSSION

**RESULTS:**

The results of the yield and organoleptic properties are shown in Table 1

**Table 1: Yield and organoleptic properties of banana peel pectin**

| Parameter | Result |
|---|---|
| % yield | 7.45 |
| Color | Brown |
| Taste | Bitter |
| Odour | Characteristics |
| Moisture content (%) | 11.5 |
| Ash content (%) | 12.05 |
| pH | 4.75 |

The yield of the banana peel pectin was 7.45%. According to Nitjaree *et al*., (2017) and Yeoh *et al*., (2008), the yield of banana peel pectin depends largely on the severity of extraction conditions including pH, type of extraction solvents and the length of extraction. Also, Emaga *et al*., (2008) highlighted that longer extraction time resulted to increase in the yield of pectins from banana peel and that yield of unripe banana peel is lower than that obtained at the mature stage.

**Table 2. Phytochemical screening on Banana peel pectin (*Musa paradisiaca*) ethanol (70%) extract**

| Phytochemical constituent | Result | Phytochemical constituent | Result |
|---|---|---|---|
| Flavonoids | + | Alkaloids | + |
| Tannins | + | Anthraquinones | - |
| Carbohydrates | + | Phytosteroids | + |
| Reducing sugar | + | Glycosides | + |
| Saponins | + | Phenols | - |
| Steroids | - | Terpenoids | - |

+ = presence; - = absence

The secondary phytochemicals of *Musa paradisiaca* were qualitatively analyzed and the results presented in Table 2. Whilst flavonoids, carbohydrates, reducing sugar, tannins, saponins, alkaloids, glycosides, phytosterols and terpenoids were detected, anthraquinones and steroids were absent in the ethanol extract.

**Table 3: Physicochemical properties of ciprofloxacin granules**

| Formulation | Angle of repose (%) | Bulk density (g /cc) | Tapped density (g/cc) | Compressibility index (%) | Hausners ratio | Flow rate (g/s) |
|---|---|---|---|---|---|---|
| Acacia 2.5% | 25.30 | 0.48 | 0.56 | 14.29 | 1.17 | 1.00 |
| Acacia 5% | 24.10 | 0.44 | 0.48 | 8.33 | 1.09 | 0.37 |
| Acacia 7.5% | 22.80 | 0.42 | 0.46 | 8.70 | 1.10 | 0.59 |
| Acacia 10% | 21.60 | 0.46 | 0.50 | 8.00 | 1.09 | 0.40 |
| PVP 2.5% | 25.00 | 0.49 | 0.53 | 7.55 | 1.08 | 0.67 |
| PVP 5% | 23.50 | 0.48 | 0.53 | 9.43 | 1.10 | 0.50 |
| PVP 7.5% | 22.00 | 0.46 | 0.50 | 8.00 | 1.09 | 0.48 |
| PVP 10% | 20.30 | 0.47 | 0.51 | 7.84 | 1.09 | 0.42 |
| BPP 2.5% | 24.20 | 0.42 | 0.47 | 10.64 | 1.12 | 0.44 |
| BPP 5% | 22.50 | 0.39 | 0.44 | 11.36 | 1.13 | 0.34 |
| BPP 7.5% | 20.00 | 0.38 | 0.45 | 15.56 | 1.18 | 0.32 |
| BPP 10% | 19.00 | 0.36 | 0.43 | 16.28 | 1.19 | 0.30 |

**Table 4. Mean and Standard Deviation of the Physicochemical Properties of Ciprofloxacin granules**

| Parameters | Acacia | PVP | BPP |
|---|---|---|---|
| Angle of repose (°) | 23.45 ± 3.50 | 17.21 ± 0.20 | 21.43 ± 2.13 |
| Bulk density (g/cc) | 0.45 ± 0.04 | 0.48 ± 0.04 | 0.39 ± 0.03 |
| Tapped density (g/cc) | 0.05 ± 0.04 | 0.52 ± 0.01 | 0.45 ± 0.03 |
| Compressibility index (%) | 8.15 ± 3.10 | 8.21 ± 0.16 | 13.46 ± 1.80 |
| Hausners ratio | 1.11 ± 0.05 | 1.09 ± 0.03 | 1.16 ± 0.03 |
| Flow rate (g/s) | 0.59 ± 0.29 | 0.52 ± 0.14 | 0.27 ± 0.07 |

The flow properties from the different formulations show that the granules had good flow characteristics. As shown in Table 4, the physiochemical properties of the ciprofloxacin granules prepared with acacia, polyvinylpyrrolidone and banana peel pectin reveal that these granules had good flow characteristics and hence indicating of good compressibility.

**Table 5. Physicochemical properties of ciprofloxacin tablets**

| Formulation binder (% w/v) | Weight variation (mg) | Hardness ($kg/cm^3$) | Friability (%) | Disintegration time (min) | Binder efficiency |
|---|---|---|---|---|---|
| Acacia 2.5% | 0.584 ± 0.03 | 4.05 ± 1.01 | 1.10 | 8.65 ± 1.20 | 0.426 |
| Acacia 5% | 0.580 ± 0.02 | 4.75 ± 0.8 | 1.00 | 10.50 ± 0.59 | 0.452 |
| Acacia 7.5% | 0.581 ± 0.04 | 5.21 ± 1.25 | 0.95 | 14.50 ± 0.23 | 0.378 |
| Acacia 10% | 0.579 ± 0.05 | 6.54 ± 1.02 | 0.85 | 18.40 ± 0.26 | 0.418 |
| PVP 2.5% | 0.581 ± 0.05 | 4.01 ± 0.07 | 1.05 | 6.40 ± 0.48 | 0.597 |

| | | | | | |
|---|---|---|---|---|---|
| PVP 5% | 0.580 ± 0.06 | 4.70 ± 0.08 | 1.00 | 9.50 ± 0.48 | 0.495 |
| PVP 7.5% | 0.582 ± 0.03 | 5.40 ± 0.12 | 0.90 | 12.75 ± 0.34 | 0.471 |
| PVP 10% | 0.580 ± 0.06 | 6.30 ± 0.20 | 0.80 | 16.20 ± 0.20 | 0.486 |
| BPP 2.5% | 0.580 ± 0.04 | 4.20 ± 0.20 | 1.00 | 7.50 ± 0.66 | 0.560 |
| BPP 5% | 0.581 ± 0.03 | 4.75 ± 0.30 | 0.86 | 12.40 ± 0.45 | 0.399 |
| BPP 7.5% | 0.579 ± 0.05 | 6.20 ± 0.04 | 0.72 | 15.00 ± 0.26 | 0.449 |
| BPP 10% | 0.581 ± 0.06 | 6.50 ± 0.03 | 0.67 | 18.20 ± 0.50 | 0.411 |

Table 5 shows the physicochemical characteristics of the various formulations of ciprofloxacin tablets (500 mg). Those formulated with acacia 2.5 – 10% w/w varied in weight from 0.579 ± 0.05 to 0.584 ± 0.03. The tablets pass the weight uniformity test as the percentage deviation falls within the acceptable limit of 5% for tablets greater than 250 mg (BP). Other formulations of PVP (2.5 – 10% w/w) and BPP (2.5 – 10% w/w) with variations of 0.580 ± 0.06 to 0.582 ± 0.03 and 0.579 ± 0.05 to 0.581 ± 0.06 respectively pass the weight uniformity test as percentage deviation falls within 5% for tablets greater than 250 mg (BP). There was significant difference in the weight uniformity test carried out across the different groups (acacia, PVP and BPP) $p > 0.5$. The hardness of all the tablet formulations pass the hardness test with values ranging from 4.05 ± 1.01 to 6.54 ± 1.02 (kg/cm$^3$) respectively. The BP specifies that the hardness of tablets with values ≥ 4 are acceptable so long as the disintergration time are not affected. It is seen that the hardness increased with increase in binder concentration. The Table also shows the friability values of all the formulations (Acacia, PVP and BPP) to range from 0.67 to 1.10%. The BP specifies a maximum limit of 1%, friability. All the formulations pass this test. The % friability however, decreased with increase in the binder concentrations. The different ciprofloxacin tablets formulated with acacia (2.5 to 7.5% w/w), PVP (2.5 to 7.5% w/w) and BPP (2.5 to 7.5% w/w) as binders all pass the disintegration time values ranging from 8.65 ± 1.2 to 14.5 ± 0.23; 6.40 ± 0.48 to 12.75 ± 0.34; and 7.50 ± 0.66 to 15.00 ± 0.26 minutes respectively. However, binder concentration of 10% w/w for acacia, PVP and BPP gave values of 18.40 ± 0.26, 16.20 ± 0.20 and 18.20 ± 0.50 minutes, values higher than the 15 minutes specified by the BP for conventional uncoated tablets.

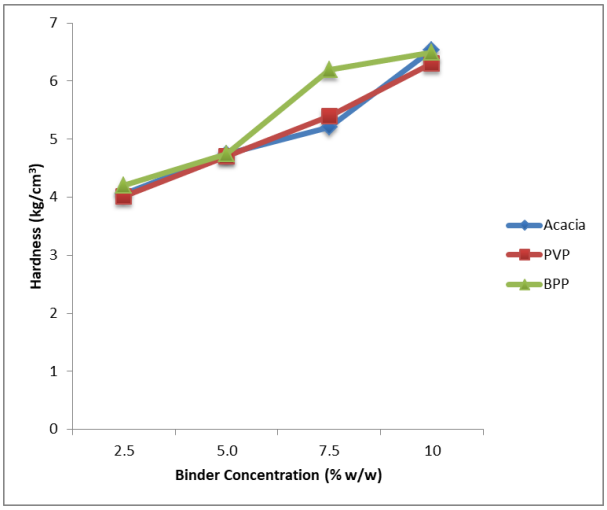


Figure 4. Hardness of ciprofloxacin tablets and binder concentration.

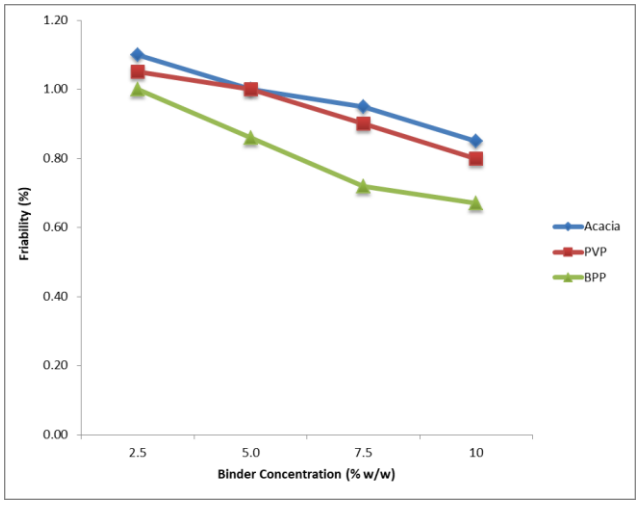


Figure 5. Friability of ciprofloxacin tablets and binder concentration

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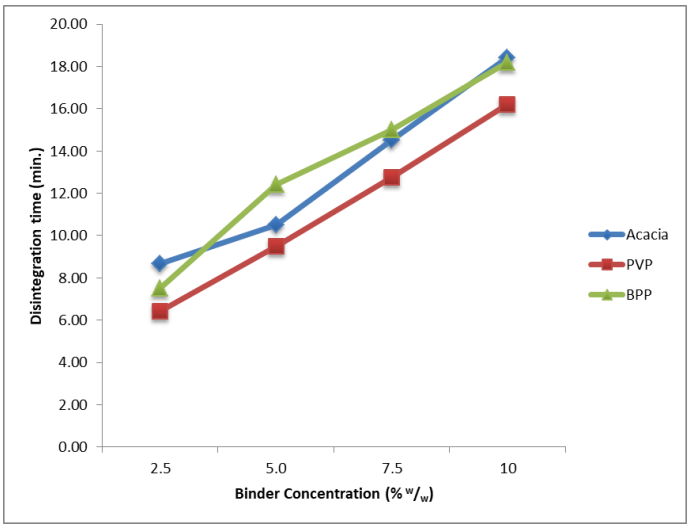



**Figure 6. Disintegration time of ciprofloxacin tablets and binder concentration.**

The binder efficiency measures the interaction between tablet hardness, friability and disintegration time. A higher binder efficiency implies that tablets formulated with it possess excellent hardness, low friability (< 1%) and short disintegration time (Alebiowu *et al*., 2009;

Lawal *et al*., 2015). As seen in Table 5, the values for binder efficiency obtained were high for all the formulations indicative of good binding property of the batches tested.

**Release profile of ciprofloxacin tablets**

The *in vitro* drug release profiles of the ciprofloxacin tablets formulated using Acacia, PVP and Banana peel pectin are shown in Figures 7, 8 and 9 respectively. Comparatively, the drug release from batches of banana peel pectin (CF 3) showed a faster release of drug content than those of Acacia and PVP. It was observed also that there was a decrease in the rate of release of the drug content as the concentration of the binders increased. The dissolution parameters are presented in Table 6. For example, the maximum drug release ($M_\infty$), time to achieve maximum release ($t_\infty$) and dissolution rate ($M_\infty/t_\infty$) for batch CF3 was 84.5% 90min and 0.939% $min^{-1}$; CF1 was 82.6%, 90min and 0.918% $min^{-1}$ respectively.

Figure 7. Release profile of ciprofloxacin tablet produced with acacia as binder.

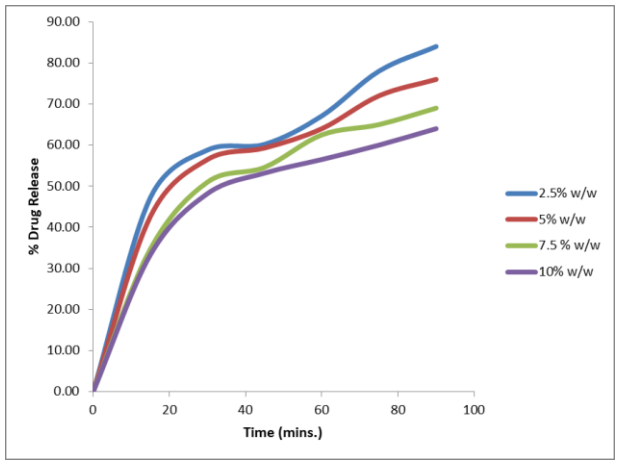
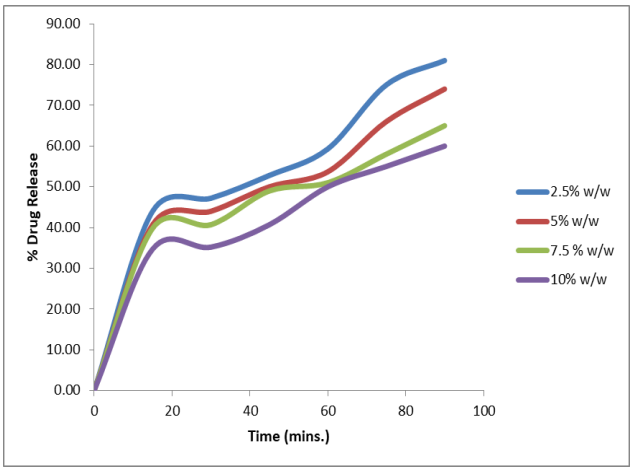



Figure 8. Release profile of ciprofloxacin tablet produced with PVP as binder.



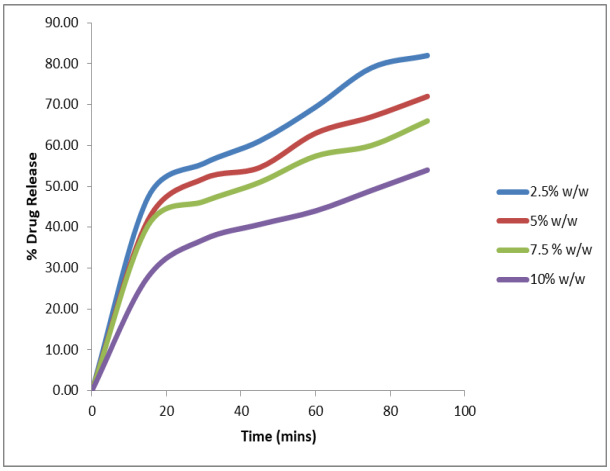



Figure 9. Release profile of ciprofloxacin tablet produced with banana peel pectin (BPP).

Table 6. Dissolution parameters of ciprofloxacin tablets.

| Batches | $M_\infty$ (%) | $t_\infty$ (min) | $M_\infty/t_\infty$ (% min) |
|---|---|---|---|
| CF 1 | 82.6 | 90 | 0.918 |
| CF 2 | 81.7 | 90 | 0.908 |
| CF 3 | 84.5 | 90 | 0.939 |

Table 7. Regression coefficient values for different release models.

| Formulations | Zero Order | First Order | Higuchi model | Korsmeyer-peppas model | Hixson-Crowell model |
|---|---|---|---|---|---|
| | $R^2$ | $R^2$ | $R^2$ | $R^2$ | $R^2$ |
| CF1(acacia) | 0.916 | 0.952 | 0.972 | 0.895 | 0.875 |
| CF2 (PVP) | 0.825 | 0.958 | 0.968 | 0.905 | 0.880 |
| CF3 (BPP) | 0.813 | 0.943 | 0.961 | 0.922 | 0.889 |

**Release kinetics and mechanism of drug release from the ciprofloxacin tablets**

The results of the various release kinetics for ciprofloxacin tablets are presented in Table 7. The results obtained from the dissolution studies were fitted into zero order, first order, Higuchi, Korsmayer-peppas, and Hixson-Crowell release models to determine the release kinetics of the different formulations. The *in vitro* release profiles of the ciprofloxacin tablets simulated the Higuchi release model as the plot showed the highest coefficient regression ($r^2$) values of 0.961 – 0.972 compared to the zero, and first order release models which had values ranging from 0.813 – 0.916 and 0.943 – 0.958 respectively. The results show that the drug released from the tablets were mainly by Higuchi's model, which states that the amount of drug released is dependent on the square root of time (Airemwen CO *et al*., 2020). This is in agreement with the studies conducted by Higuchi, 1963. In this study he analyzed the mechanism of drug release from matrices and postulated two mechanisms which are dissolution and diffusion controlled mechanisms (Higuchi T, 1963).

## IV. Conclusion

Agricultural wastes are biodegradable materials which are currently being converted to wealth in the pharmaceutical industries as excipients in pharmaceutical dosage forms, as well as in food industries for various functions as adjuvants and as suspending agents. Banana peel wastes are numerous and could constitute environmental nuisance, pectin which is widely used in the preparation of some pharmaceutical dosage forms; in the food and paint industries as thickners; can be derived in commercial amounts from this natural plant source – banana peel (*Musa paradisiaca*). The results from this research has showed that banana peel pectin can truly be employed as a binder in ciprofloxacin tablet formulation.

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## AUTHORS

**First Author** – Obarisiagbon, Department of Pharmaceutics and Pharmaceutical Technology, College of Pharmacy, Igbinedion University, Okada, Edo State, Nigeria., E-mail: obarisiagbon.a@iuokada.edu.ng, Phone: +2348037705865
**Second Author** – Aiwaguore Johnbul, Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmacy, University of Benin, Benin City, Edo State, Nigeria
**Third Author** – Airemwen,
**Fourth Author** – Collins Ovenseri,
**Fifth Author** – Obianuju,
**Sixth Author** – Jennifer Chude,