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Potential Use of *Musa Sapientum* Peel Gum as Adhesive in Paracetamol Tablets

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ABSTRACT

This work is an attempt at converting waste products from food, peels of *Musa sapientum* into useful pharmaceutical excipient. The gum from the peels was extracted, dried and pulverized by an already established method. A similar process was carried out with *M. acuminata* peels. Interaction studies were carried out using differential scanning calorimetry (DSC). Paracetamol granules were prepared with mucilage of the gums extracted from the peels at concentrations of 2, 4, 6, 8, and 10%$^{w}/_{w}$ of tablet weight using the mucilage and employing the wet granulation approach. Similar batches of paracetamol granules were prepared using sodium carboxymethyl cellulose (SCMC). The flow and compressibility properties of the granules were evaluated. The granules were compressed into tablets and evaluated for hardness, friability, disintegration and dissolution. The DSC results reveal that the gum is compatible with paracetamol. Also the gum compared favorably with that of *M. acuminata* and also SCMC in terms of compact characteristics, such as hardness [*M. sapientum*- 2% (6.55±0.86); 4% (6.00±0.53); 6% (5.60±0.39); 8% (5.50±0.67); 10% (5.35±0.46): *M. acuminata*- 2% (4.60±0.74); 4% (5.65±0.53); 6% (5.50±0.33); 8% (6.00±0.41); 10% (6.45±1.07): SCMC – 2% (6.55±0.28); 4% (9.23±1.20); 6% (11.65±2.74); 8% (13.39±2.13); 10% (6.20±2.45)], disintegration [*M. sapientum* – 2% (11±1.7sec); 4% (10±0.9 sec); 6% (15±1.4 sec); 8% (12±1.4 sec); 10 (11±1.4 sec): *M. acuminata* – 2%

(19±1.4 sec); 4% (17±1.3 sec); 6% (12±1.0 sec); 8% (13±0.9 sec); 10% (18±0.9 sec): SCMC – 2%, 4%, 6%, 8% and 10% > 15mins]. Drug release from the tablets formulated with the *M. sapientum* gum was rapid, reaching 100% within 30 minutes. This is similar to the release profile of tablets formulated with *M. acuminata,* whereas tablets formulated with SCMC had much longer release times. Friability values were higher with *M. sapientum* gum – 2% (14.56%); 4% (23.73%); 6% (15.03%); 8% (14.18%); 10% (14.57%): *M. acuminata* – 2% (11.76%); 4% (8.08%); 6% (10.58%); 8% (3.29%); 10% (0.18%): SCMC – 2% (1.61%); 4% (0.21%); 6% (0.11%); 8% (0.09%); 10% (0.28%), thus admixtures with SCMC might be a good option. The gum from *M. sapientum* gave a yield of 65% ($^{w}/_{w}$) which was high and the starting material is readily available. Thus, it could be an alternative source of adhesives suitable to be employed for the manufacture of immediate release paracetamol tablets.

Key Words: *Musa sapientum, Musa acuminata*, Peels, Paracetamol, Sodium Carboxymethyl Cellulose (SCMC), Tablets, Immediate-release

INTRODUCTION

In recent years, plant-derived polymers have evoked tremendous interest as pharmaceutical excipients due to their diverse applications in drug formulation such as diluents, binders, disintegrates in tablets, thickeners in oral liquids, protective colloids in suspensions, gelling agents in gels and bases in suppositories (1,2,3,4,5). These polymers such as natural gums and mucilage are biocompatible, cheap and easily available and are preferred to semi synthetic and synthetic excipients because of their lack of toxicity, low cost, availability, soothing action and nonirritant nature (2,6).

Gums possess a complex, branched polymeric structure thus they exhibit high cohesive and adhesive properties. Such properties are used in pharmaceutical preparations. These polymers are useful as tablets binder, (7,8) disintegrating agent, emulsifier (9,10), suspending agent, thickener, (11,12) gelling agent, stabilizing agent, protective colloids in suspension and sustaining agent in tablets (13-16).

Use of natural gums as pharmaceutical excipients is attractive because they are economical, readily available, nontoxic, capable of chemical modifications, potentially biodegradable, and with few exceptions, also biocompatible (17). The adhesive efficacy of some gums has been evaluated in tablet formulations and they have promise e.g. *Corchorus olitorius* (18), *M. acuminata* peels (2), *Moringa oleifera* (3) and *Phoenix dactyfera* Linn (date palm) (19).

Musa acuminata Colla is wild banana that belongs to the plant family Musaceae.

In the South Pacific, ripe bananas and plantains are mashed, mixed with coconut cream and scented with citrus leaves to make a thick fragrant drink. In Costa Rica, the ripe bananas are peeled and boiled slowly for several hours to make thick syrup called 'honey' (20). The peel of dried banana has high tannin content and is used to color leather. The ash from the dried peel of the banana is rich in potash and is used in soap-making (20).

Extracts of the leaves are used to treat bronchitis and diabetes. The astringent plant sap is reputed to be effective in treating hysteria, epilepsy, fever, and diarrhea and can also relieve hemorrhoids, insect bites and stings. The young leaves are used as poultices on burns. The roots extracts are used for digestive problems. The peel and pulp of ripe bananas are found to have anti-fungal and antibiotic properties (20).

The aim of this study is to evaluate the adhesive properties in tablet formulations of the gum extracted from unripe peels of *M. sapientum.* Furthermore, it aims to compare them with those of a natural and similar source, *M. acuminata* (which has previously been evaluated), and a semi-synthetic polymer as well as sodium carboxylmethylcellulose (SCMC).

EXPERIMENTAL

Materials

Paracetamol powder was a gift from Chazmax Pharmaceuticals, Obosi, Anambra State, Nigeria. Corn starch, sodium carboxymethyl cellulose (SCMC), magnesium stearate, sodium metabisulphate and sodium hypFochlorite were supplied by a vendor, Anselem Chemicals, and characterized before use.

Methods

Collection of plant material

Freshly harvested unripe bundle-heads of *M. sapientum* and *M. acuminata* were procured from a local market at Nawfia, Anambra State, Nigeria and identified by a taxonomist, Mr. A.O. Ozioko of the Bio-resources Development Conservative Programme Centre in Nsukka, Enugu state, Nigeria. The bundle-heads of both *M. sapientum* and *M. acuminata* were unbundled, peeled and the peels washed and allowed to drain.

Extraction and Preparation of the Gum Mucilage

The method used to extract the gum was as previously outlined by Osonwa *et al.* (2). The peels were washed with purified water and bleached by soaking in a 0.02% sodium hypochlorite solution for 36 hours to wash off chlorophyll and other colored matters, after which the bleaching solution was discarded. A 0.1% Sodium metabisulphate solution was added as an antioxidant to prevent darkening of the peel upon exposure to atmospheric oxygen (21). It was then dried in a hot-air oven at 60 °C and milled with a grinding machine. The powder was sieved with sieve number 0.12 mm. The equivalent quantities of gum powder to give 2, 4, 6, 8, and 10%$^{w}/_{w}$ of the intended formulation respectively, were used to prepare mucilage.

Preparation of Paracetamol Granules

Granules of paracetamol (50g) were made by wet granulation with corn starch (as disintegrant) and mucilage of powdered banana (*M. sapientum*) gum at concentrations of 2, 4, 6, 8, and 10%. The granules were dried, sieved through 1.00 mm screen and stored at room temperature conditions in airtight plastic containers for characterization before compression into tablets.

The process was repeated with the mucilage of powdered plantain (*M. acuminata)* gum and sodium carboxymethyl cellulose (SCMC) used at equivalent concentrations (*Table 1*) to granulate paracetamol powder.

Evaluation of the prepared paracetamol granules

Granule properties such as tapped density, bulk density, Hausner's ratio, Carr's compressibility index, flow rate, angle of repose, and percentage fine were determined by standard methods and recorded.

The volume of a known quantity of the granules from each batch was obtained before and after tapping. The volume before tapping was used to determine the bulk density while the volume after

tapping was employed to determine the tap density mathematically.

Furthermore, Hausner's quotient and Carr's compressibility index used to determine the flow and compressibility properties of granules were calculated:

Equation 1:

Bulk Density = weight of granules (grams)/volume before tapping (milliliters)

***Equation 2*:**

Tapped Density = weight of granules (grams)/volume after tapping (milliliters)

***Equation 3*:**

Hausner's quotient = Tapped Density/Bulk Density

Equation 4:

Carr's Compressibility Index = $\frac{\text{Tapped Density} - \text{Bulk Density}}{\text{Tapped Density}} \times 100/1$

Equation 5:

Flow rate was calculated by determining the time taken for a known mass of granules to flow through an orifice; whereas angle of repose was derived from the height and diameter of the heap formed by the granules after flowing through the orifice. Percentage fine was determined mathematically after separating fine granules from the coarse granules by passing through a sieve of pore size No. 44.

Flow rate = weight of granules (grams)/time of flow (seconds)

Equation 6:

Angle of repose ($Tan^{-}\theta$) = Height of cone (cm)/radius of cone (cm)

Equation 7:

Percentage fine = $\frac{\text{Weight of fine} \times 100}{\text{Total weight of granules (fine + coarse)}}$.

Compression of granules

The granules were blended with the lubricant (magnesium stearate 1%$^{w}/_{w}$). The blend was compressed using a 10-station rotary tablet press (Proton multiple punch rotary press, India) set at 933 (N/m^2). The die-volume was set to obtain 500mg paracetamol tablets.

Table 1:

Composition of tablets

Batch	P.P	B.P	SCMS	PCM	Disintegrant (12.2%)	Lubricant (1%)
A1	2% (10.87mg)	-	-	500mg	27.2mg	5.4mg
A2	4% (22.20mg)	-	-	500mg	27.8mg	5.6mg
A3	6% (34.10mg)	-	-	500mg	28.4mg	5.7mg
A4	8% (46.50mg)	-	-	500mg	29.1mg	5.8mg
A5	10% (59.50mg)	-	-	500mg	29.7mg	5.9mg
B1	-	2% (10.87mg)	-	500mg	27.2mg	5.4mg
B2	-	4% (22.20mg)	-	500mg	27.8mg	5.6mg
B3	-	6% (34.10mg)	-	500mg	28.4mg	5.7mg
B4	-	8% (46.50mg)	-	500mg	29.1mg	5.8mg
B5	-	10% (59.50mg)	-	500mg	29.7mg	5.9mg
C1	-	-	2% (10.87mg)	500mg	27.2mg	5.4mg
C2	-	-	4% (22.20mg)	500mg	27.8mg	5.6mg
C3	-	-	6% (34.10mg)	500mg	28.4mg	5.7mg
C4	-	-	8% (46.50mg)	500mg	29.1mg	5.8mg
C5	-	-	10% (59.50mg)	500mg	29.7mg	5.9mg

P.P=Plantain peels (M. acuminata), B.P=Banana peels (M. sapientum), SCMC=Sodium CarboxyMethyl Cellulose, PCM=Paracetamol

Evaluation of tablets

Mechanical property

The standard methods for tablet hardness and friability determination were used to evaluate the mechanical properties of the tablets and recorded.

Ten (10) tablets were randomly selected from each of the batches and their mechanical strength evaluated using Monsanto Hardness Tester (Coslab). The pressure taken to crush the tablet was recorded in kgF. The mean and standard deviation of the tablet hardness were determined.

Tablet friability was determined by randomly selecting ten (10) tablets from each batch, dusted and weighed. The tablets were placed in a Roche friabilator (Erweka Gmbh, Germany) and subjected to its tumbling actions at 25 revolutions per minute for four minutes. Afterwards, the tablets were once again dusted and reweighed to determine the percentage loss of weight. The percentage friability was calculated using the equation below.

Equation 8:

$$\% \text{ friability} = \frac{\text{Initial weight} - \text{final weight}}{\text{Initial weight}} \times 100$$

Disintegration test

For the disintegration test of the tablets, Erweka disintegration apparatus with 0.1N HCl as the disintegration medium maintained at 37± 1°C, was used for the analysis. Six (6) tablets selected at random from each of the batches, were each placed in a tube of the disintegration unit. Via the upward and downward movement in the medium, the time taken for each tablet to completely break down to particles that pass through the wire mesh was recorded. The mean of the determinations was calculated (22).

Dissolution test

Drug release studies of all the batches were carried out using tablet dissolution test apparatus at 50 rpm. 900 ml of 0.1N HCl at pH1.2 was used as the dissolution medium with temperature maintained at 37±2°C in all experiments. 5 mL of sample was withdrawn at 5 min interval for times 5, 10, 15, 20, 25 and 30 minutes respectively and replaced with fresh medium to maintain sink conditions. Samples withdrawn were analyzed at 257nm for percentage drug release using Shimadzu UV-Visible spectrophotometer.

The concentrations were then calculated using the constant K obtained from Beer's calibration:

$$A = K*C.$$

Where:
A = Absorbance,
C= Concentration
K= constant

Results and Discussion

Yield of the Gum and Appearance

The percentage yields of the gums calculated on dried weight basis were 67% and 65% ($^{w}/_{w}$) for *M. acuminata* and *M. sapientum,* respectively. The high percentage yield of the gums is indicative that the gums can be easily processed in bulk and commercialized for industrial application.

The color of the gums (*M. acuminata* and *M. sapientum*) was slightly milky. This is an indication that the gums can be effectively applied in pharmaceutical production without causing any setback by discoloring the final products.

Pre-formulation Studies

Physicochemical Analysis

Analysis to determine some of the physicochemical properties of the gum such as Solubility test, Loss on drying, Total ash value, and Acid insoluble ash was carried out and the results were recorded (*Tables 2 and 3*).

Table 2:

Solubility test for *M. sapientum* gum

Sample	Solvent system			
	Water	5% NaOH	5% $NaHCO_3$	5% HCl
M. sapientum gum	Insoluble	partially soluble	partially soluble	insoluble

Table 3:

Physicochemical parameters

Parameters	Percentage ($\%^{w}/_{w}$)
Loss on Drying	11.95 ± 0.07
Total Ash	4.235 ± 0.02
Acid insoluble ash	0.28 ± 0.05

Phytochemical Analysis

Phytochemical analysis was carried out to identify the phytochemical composition of the natural gums. *M. acuminata* gum has morphine alkaloids, which is absent in *M. sapientum*. *M. sapientum* gum has quinolone alkaloids, which is absent in *M. acuminata* gum. *Tables 4* and *5* show the phytochemical composition of the gums *M. sapientum* and *M. acuminata* respectively.

Table 4:

Phytochemical Composition of *M. sapientum*

Phytochemicals Present	**Phytochemicals Absent**
Tannins	Saponins
Alkaloid (Wagner Test)	Flavone
Alkaloid (Meyer Test)	Glycoside
Quinolone Alkaloid	Indole Alkaloid
	Morphine Alkaloid
	Purine Alkaloid

Table 5:

Phytochemical Composition of *M. acuminata*

Phytochemicals Present	**Phytochemicals Absent**
Tannins	Saponins
Alkaloid (Wagner Test)	Flavone
Alkaloid (Meyer Test)	Glycoside
Morphine Alkaloid	Indole Alkaloid
	Quinolone Alkaloid
	Purine Alkaloid

Elemental Analysis

Elemental analysis was evaluated to determine the concentrations of metals present in the sample (*Table 6*).

Table 6:

Concentration of Elements measured in the *M. sapientum* gum

Sample	***M. sapientum* gum**				
Essential Metals	**Ca**	**K**	**Mn**	**Na**	**Zn**
Mean Concentration (mg/L)	4280.78 ± 5.13	7299.5 ± 3.20	7.35 ± 0.07	6241.6 ± 7.75	24.425 ± 0.18
Non-Essential Metals	**Co**	**Cr**	**Pb**		
Mean Concentration (mg/L)	0.05	132.88 ± 6.47	0.325 ± 0.04		

Compatibility Studies

The results of the compatibility studies using DSC are shown in *Figures 1-5*. There is no extra peak formed nor any extra thermographic event between the drug and *M. sapientum* gum. Also, the gum does not interact with other excipients used in the formulation. This is a desired property as any interaction could affect the stability of the API.

Figure 1:

DSC thermogram of M. sapientum gum

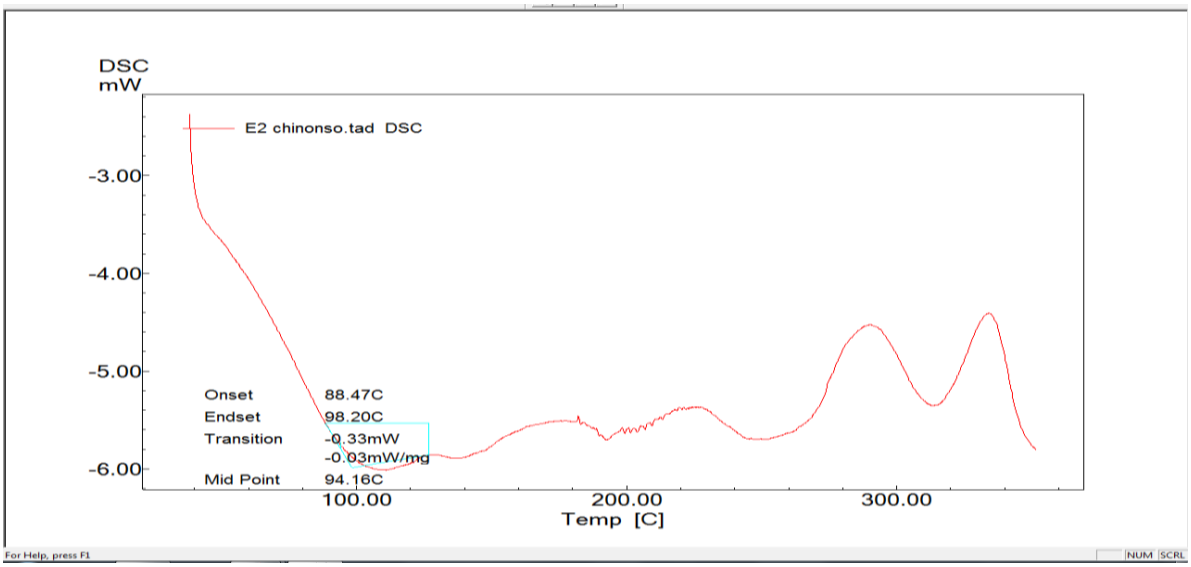


Figure 2:

DSC thermogram of Corn Starch

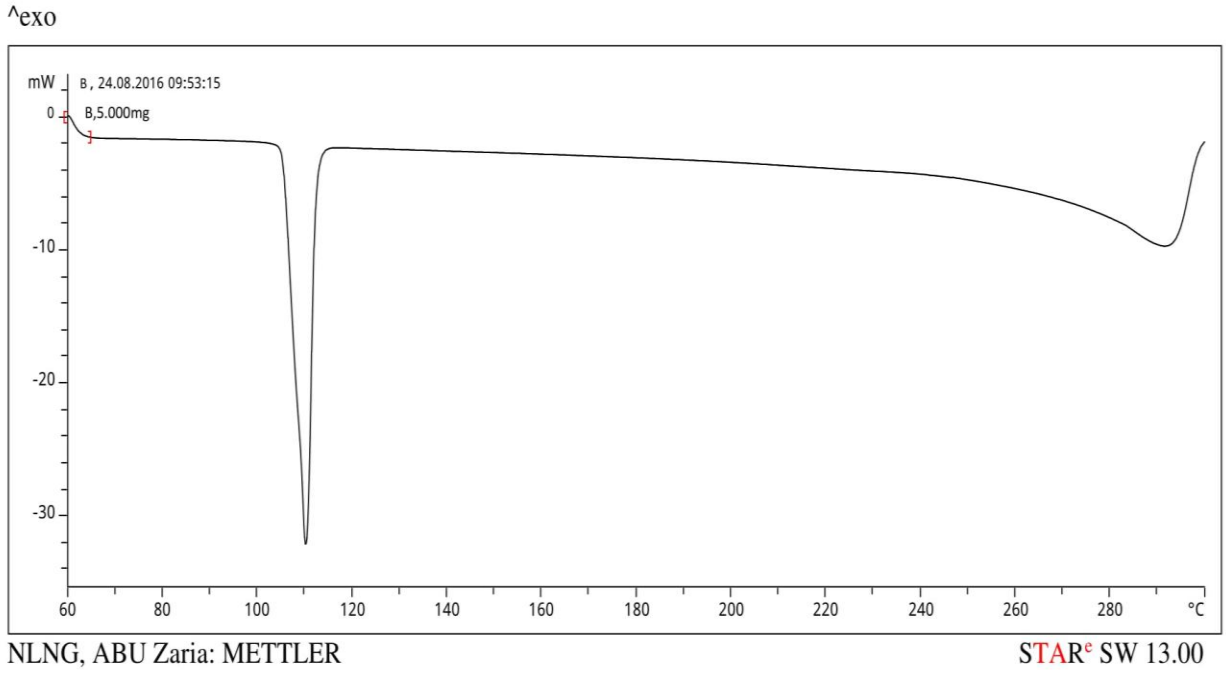


Figure 3:

DSC thermogram of Magnessium Stearate

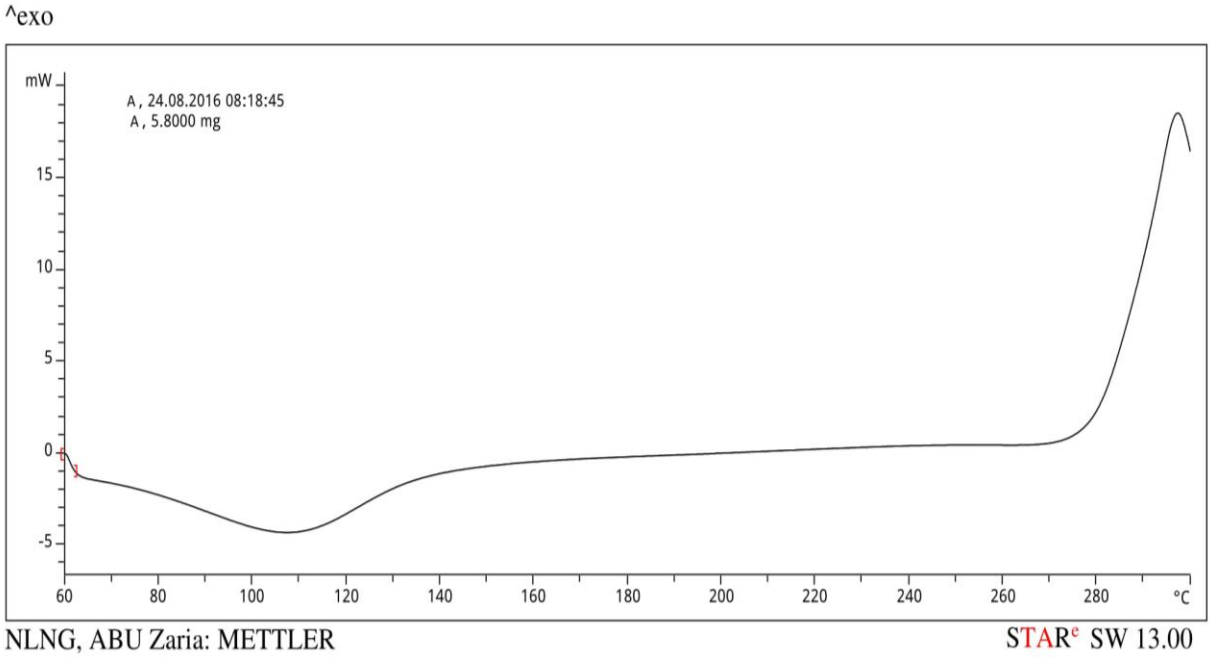


Figure 4:

DSC thermogram of Pure PCM powder

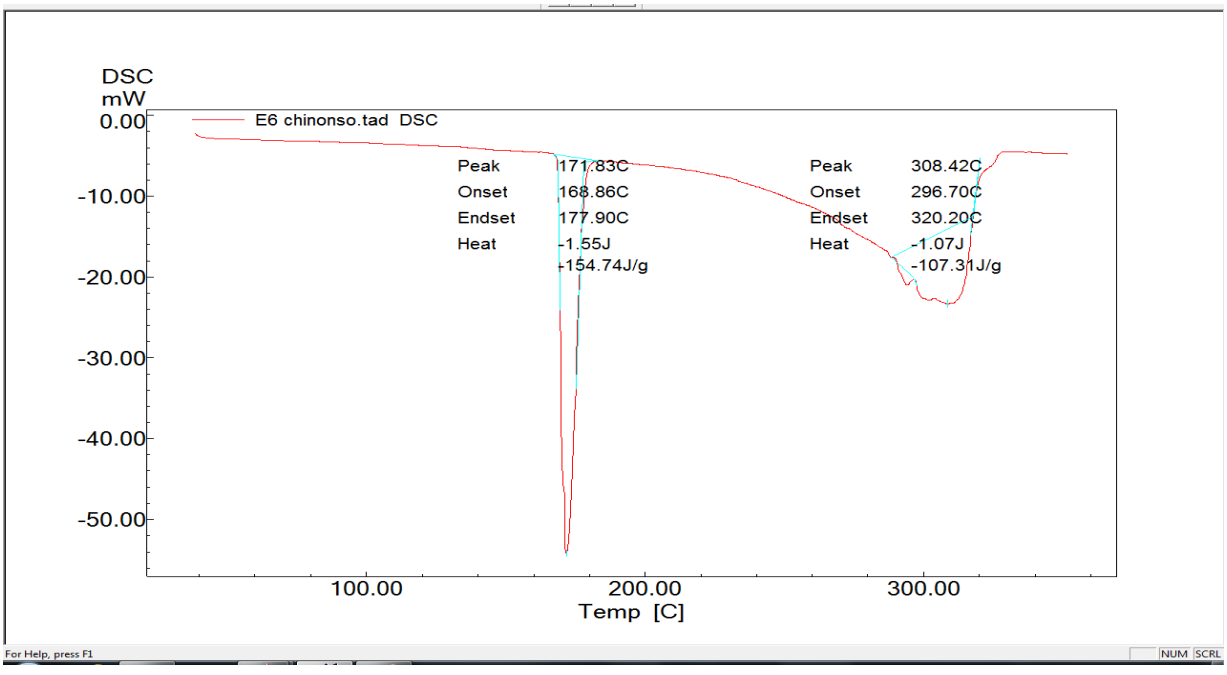
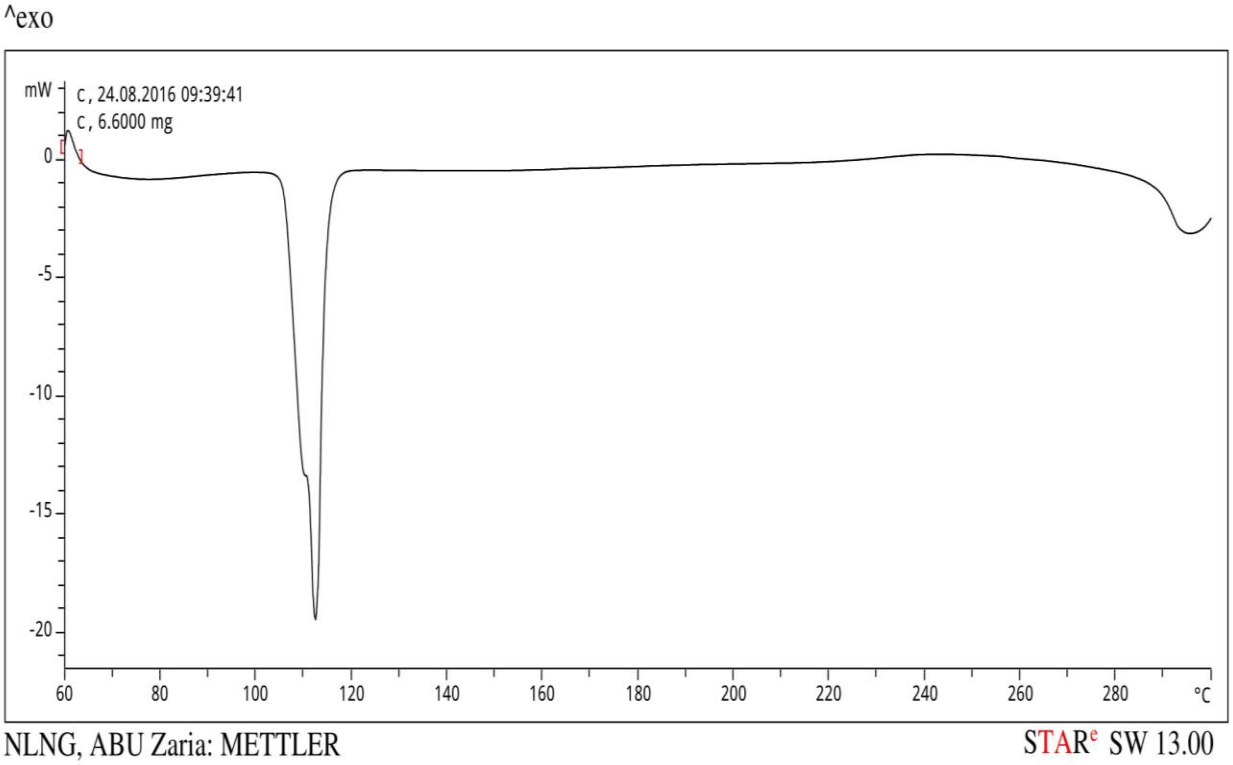


Figure 5:

DSC thermogram of pure PCM powder mixed with the excipients



Granule Characteristics

The results of the granules properties such as angle of repose, flow rate, Hausner's quotient, Carr's compressibility index, percentage fine, are as shown in *Table 7*. Granules with good flow properties have their values of the angle of repose, Hausner's ratio and Carr's index as < 30 °C, < 1.25 and <25% respectively (8, 23, 24, 25).

Angle of repose is a characteristic of the internal friction or cohesion of the particles. It gives an insight into the flowability of the powder or granule assessed (18, 26). Its value has an inverse relationship to the flow rate of powder or granule mass (27). From the results, it was observed that the granules prepared with the gums from *M. acuminata* and *M. sapientum* have similar values of angle of repose with the granules prepared with the commercial binder SCMC, although their values of $>50^{o}$ indicates unsatisfactory flow properties.

Paracetamol granules prepared with *M. sapientum* gum exhibited a gradual decrease in flow rate as the adhesive material concentration increased. This is similar to the property exhibited by the *M. acuminata* gum. The gradual decrease in flow rate was observed from 2% concentration through 6% concentration after which there was increased flow rate for batches 8% and 10% concentrations of *M. sapientum* gum; whereas increased flow rate was

observed for batch 10% concentration of *M. acuminata* gum.

Hausner's ratio and Carr's compressibility index were used to determine the ability of the granules to compact and decrease in volume when pressure is applied. These measure the inherent properties of the granules to form strong and stable compact mass (26).

Compressibility index is also indicative of the flow properties of granules while Hausner quotient relates to the cohesiveness of the granules (19,28).

When the percentage compressibility is below 15% the granules have excellent flow properties while cohesive granules have percentage compressibility above 25% indicating poor flow properties (23,24). Granules with Hausner ratio below 1.25 have good flow properties (8) and granules with angle of repose below 40º but preferably below 30º exhibit good flow (25) while granules with 50º would flow with difficulty (29).

The granules prepared with *M. sapientum* gum and SCMC all gave satisfactory values for Hausner's ratio and Carr's compressibility index at values below 1.25 and 25% respectively, whereas granules prepared with *M. acuminata* gum gave values of Hausner's ratio above 1.25 apart from the batch prepared with 4% *M. acuminata* gum, which gave a value of 1.21. All the granule batches prepared with *M. acuminata* gum gave satisfactory results for Carr's compressibility index.

Therefore, the results are indicative that the flow properties of granules formulated with the *M. sapientum* gum competes with those of *M. acuminata* as well as those of SCMC.

Table 7:
Granule Properties

Batches	Flow Rate (g/sec) *mass of granules=10g	Angle of repose (°)	Percentage fine (%)	Hausner ratio	Carr's Index
A1	1.961	59.31	13.87	1.33	24.6
A2	1.538	57.32	12.46	1.21	17.6
A3	1.449	56.7	9.6	1.27	21.1
A4	1.429	59.03	13.76	1.33	25
A5	1.613	57.32	12.73	1.27	21.1
B1	1.852	56.49	14.7	1.2	17
B2	1.639	59.59	11.83	1.16	13.5
B3	1.471	59.03	8.29	1.15	12.7
B4	1.587	55.38	10.71	1.18	15.2
B5	1.563	54.52	8.4	1.12	10.5
C1	1.351	58.75	9.83	1.2	16.7
C2	1.449	56.35	9.27	1.17	14.3
C3	1.429	59.03	7.64	1.14	12.3
C4	1.429	55.77	8.39	1.2	16.4
C5	1.333	62.2	10.47	1.23	18.4

A1=2% M. acuminata gum; A2=4% M. acuminata; A3=6% M. acuminata; A4=8% M. acuminata; A5=10% M. acuminata; B1=2% M. sapientum; B2=4% M. sapientum; B3=6% M. sapientum; B4=8% M. sapientum; B5=10% M. sapientum; C1=2% SCMC; C2=4% SCMC; C3=6% SCMC; C4=8% SCMC; C5=10% SCMC

Statistical Analysis (Tables 9-12)

Analysis of variance (ANOVA) was used to analyze the significance of the physicotechnical properties of the binders on Paracetamol tablets. Further, Post-Hoc Test comparing the natural binders with the synthetic binder was done using Dunnet 2-sided T-test. Also Paired T-test was used to compare the significance levels of the properties of the two binders. Significance level for the analysis was fixed at 0.01 levels of significance.

Evaluation of tablets properties

The properties of the tablets such as hardness, friability, disintegration, were evaluated and the results shown in *Table 8*. *Figures 6-13* show the dissolution profiles.

Hardness test also known as crushing strength aims to measure the ability of tablets to withstand pressure or stress during handling, packaging and transportation with no permanent deformation (19). As stated by Allen *et*

al., (2004) (30), for the hardness test for a tablet to be satisfactory, the minimal crushing strength should be greater than or equal to 4kgf; *Table 7* shows that the hardness test values of all the batches are within acceptable range. While the 8% concentration of the commercial binder (SCMC) yields tablets with the highest crushing strength (13.39kg/cm) whiles the 2% concentration of the *M. acuminata* gum yields tablets with the least crushing strength (4.60kg/cm).

Deviation from the mean hardness values for the three (3) binders is significant at P-value 0.000 for binder concentrations 2%, 4%, 6% and 8%, whereas it is not significant at P-value 0.275 for the 10% concentration. At 2% concentration, mean hardness of the paracetamol tablet prepared with *M. sapientum* gum varied significantly with the tablet prepared with the SCMC gum, whereas the mean hardness of tablets prepared with *M. acuminata* gum at same concentration (2%) did not vary significantly with the tablets prepared with SCMC gum with P-value of 1. At 10% concentration, mean hardness of the tablets formulated with both *M. sapientum* and *M. acuminata* gums varied insignificantly with the mean hardness of the tablets formulated with SCMC gum. Hardness values of both natural gums however, varied significantly with that of the synthetic gum at concentrations of 4%, 6% and 8%. Paired T-test comparing the two natural gums showed the P-value to be significant between 2% concentration of the gums at 0.000 but not significant at 4%, 6%, 8% and 10% concentrations at 0.066, 0.555, 0.085 and 0.028 respectively.

Percentage friability is another mechanical property of a tablet with compendia (USP, 1995) specification of not more than 1% (31). While crushing strength test is a measure of bulk deformation of the tablet, friability is a measure of surface deformation which among other things is impacted by the morphology of the tablet (19,32). The effect of tablet morphology on the friability property was evident in the results obtained. Batches A5 (10% *M. acuminata* gum), C2 (4% SCMC), C3 (6% SCMC), C4 (8% SCMC), C5 (10% SCMC) passed the friability test with values below 1% as shown in *Table 8*, while the other batches did not meet the compendial specification.

Disintegration of tablets is a vital step in the release process of the drugs from immediate release formulations. The rate of disintegration is directly proportional to the rate of dissolution. The rate of disintegration is influenced by the rate of influx of water into the tablets which is also dependent on the porosity of the tablets (19). Except for the batches prepared with the commercial binder (SCMC) which did not meet the specification with disintegration time within 15 minutes, all other batches showed a very rapid disintegration time. The variation of the mean disintegration times of the tablets formulated with *M. sapientum* gum, *M. acuminata* gum and SCMC is significant at 0.01 level of significance for all the concentrations (2%, 4%, 6%, 8% and 10%) of the gums.

Post hoc test (Dunnet 2-sided T-test) comparing the two natural gums (*M. sapientum* and *M. acuminata*) against the synthetic binder (SCMC), revealed

that the mean difference of the disintegration times is significant for the comparisons at 0.01 level of significance for all the concentrations. Two-sided T-test was conducted to compare the two natural gums and revealed that the mean difference is insignificant for the 8% concentration of the gums and significant for the 2%, 4%, 6% and 10% concentrations of the gums at 0.01 level of significance.

Tablet dissolution rate is the most important characteristic of a tablet. The dissolution test measures the time required for a given percentage of the drug substance in a tablet to go into solution (2). Dissolution rate of any given drug directly determines the extent and rate of the drug's absorption and ultimately its therapeutic outcome for BCS classes I and II drugs. Formulations with prolonged dissolution produce extended or reduced therapeutic effects, whereas those with immediate or rapid release profiles produce immediate onset of therapeutic actions. The factors that affect dissolution include type and concentration of adhesive, hardness, surface area, solubility of the drug, manufacturing process (wet granulation, dry granulation or direct compression) and diluents (19). USP individual monograph specifications for Paracetamol (acetaminophen) states that paracetamol tablet formulation is acceptable if not less than 80% of the labeled drug is dissolved in 30 minutes (35).

The batches of paracetamol tablets formulated with *M. sapientum* gum (2%, 4%, 6%, 8% and 10%) satisfied the acceptability criteria by releasing more than 80% of the API within 30 minutes.

Comparable results were recorded for the batches prepared with *M. acuminata* gum and 10% of SCMC, however 2%, 4%, 6% and 8% SCMC formulations did not release up to 80% of the API before 30mins and thus did not satisfy the acceptability criteria. Dissolution time graphs for the different batches of paracetamol formulations are as shown in *Figures 6-13*. The results show that tablets formulated with *M. sapientum* gum compared favorably with those formulated with *M. acuminata* gum and both gums produced tablets with rapid dissolution rate whereas tablets formulated with SCMC produced moderately longer dissolution rate.

Table 8:
Physicotechnical Analysis

Batch ID	Hardness	Percentage Friability	Disintegration Time ± SD
A1	4.6 ± 0.74	11.76%	19 secs ± 1.4
A2	5.7 ± 0.53	8.08%	17 secs ± 1.3
A3	5.5 ± 0.33	10.58%	12 secs ± 1.0
A4	6.0 ± 0.41	3.29%	13 secs ± 0.9
A5	6.5 ± 1.07	0.18%	18 secs ± 0.9
B1	6.6 ± 0.86	14.56%	11 secs ± 1.7
B2	6.0 ± 0.53	23.73%	10 secs ± 0.9
B3	5.6 ± 0.39	15.03%	15 secs ± 1.4
B4	5.5 ± 0.67	14.18%	12 secs ± 1.4
B5	5.4 ± 0.46	14.57%	11 secs ± 1.4
C1	6.6 ± 0.28	1.61%	914 secs ± 1.5
C2	9.2 ± 1.20	0.21%	923 secs ± 2.8
C3	11.7 ± 2.74	0.11%	1013 secs ± 4.5
C4	13.4 ± 2.13	0.09%	935 secs ± 6.3
C5	6.2 ± 2.45	0.28%	1104 secs ± 6.4

A1=2% M. acuminata gum; A2=4% M. acuminata; A3=6% M. acuminata; A4=8% M. acuminata; A5=10% M. acuminata; B1=2% M. sapientum; B2=4% M. sapientum; B3=6% M. sapientum; B4=8% M. sapientum; B5=10% M. sapientum; C1=2% SCMC; C2=4% SCMC; C3=6% SCMC; C4=8% SCMC; C5=10% SCMC

Figure 6:

***In vitro* dissolution test for paracetamol tablet formulated with *M. sapientum* peels gum as binder**

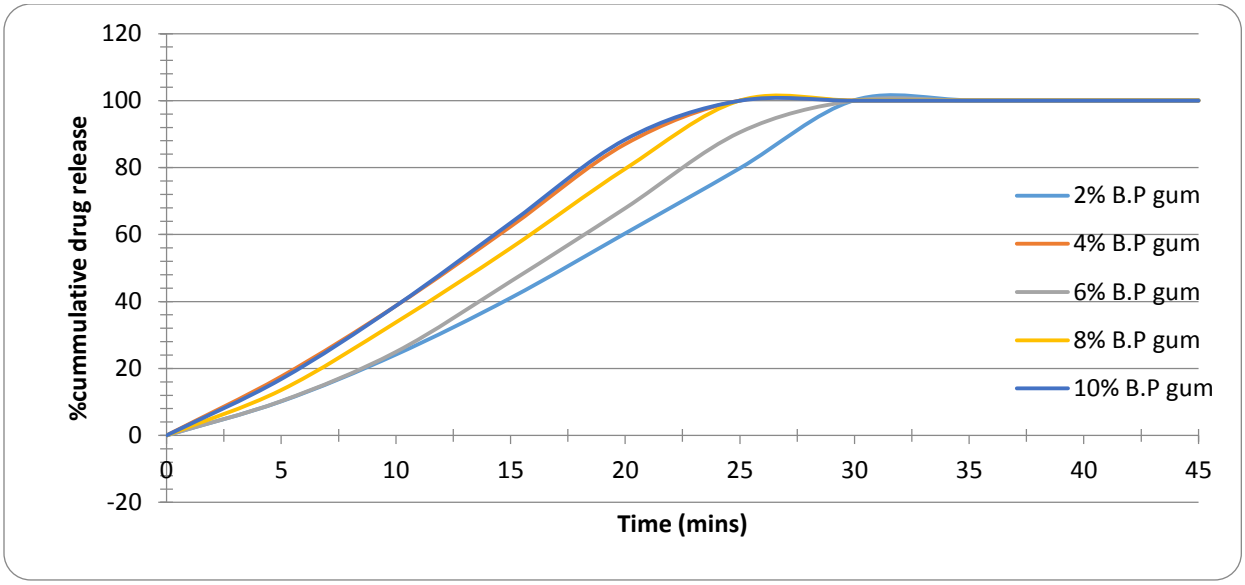


Figure 7:

***In vitro* dissolution test for paracetamol tablet formulated with *M. acuminata* peels gum as binder**

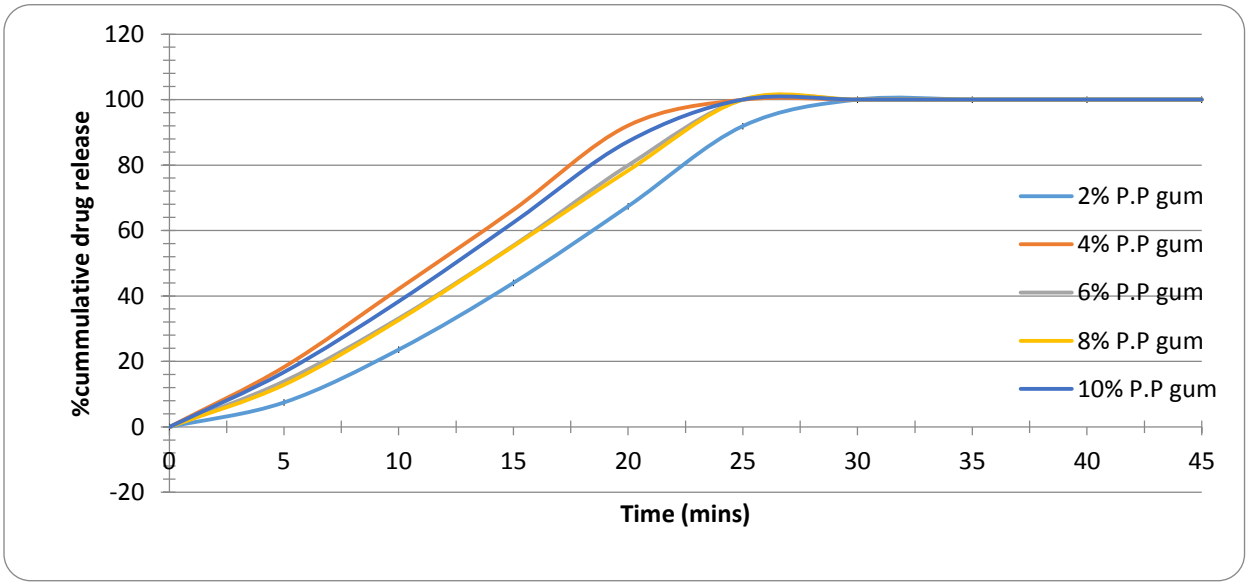


Figure 8:

***In vitro* dissolution test for paracetamol tablet formulated with SCMC binder**

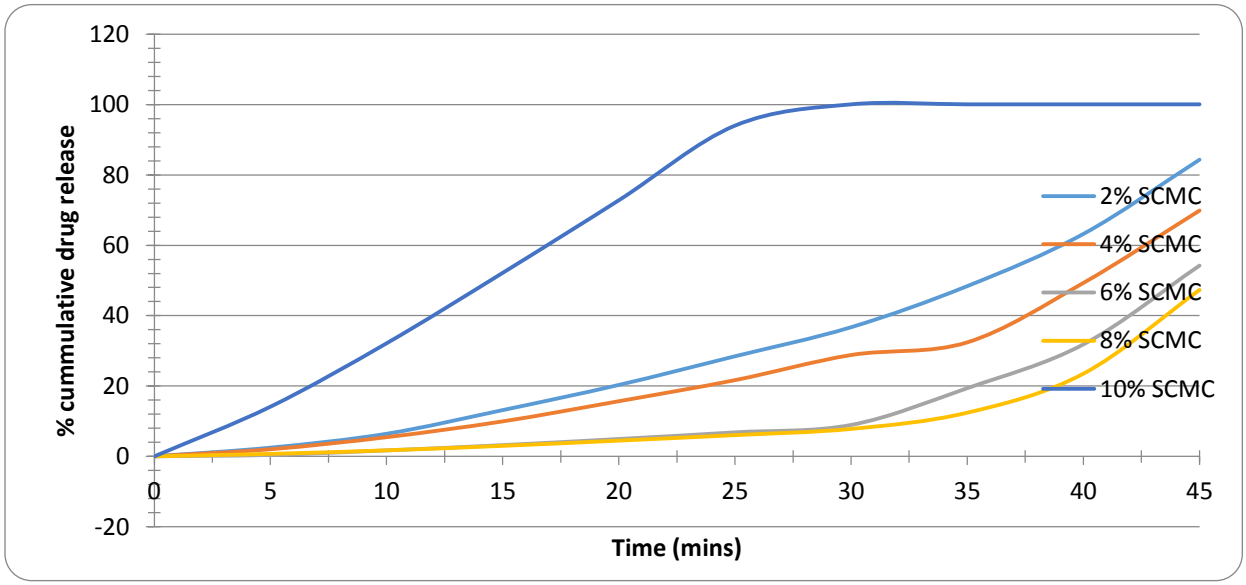


Figure 9:

***In vitro* dissolution test for Paracetamol tablet formulated with 2% of the binders**

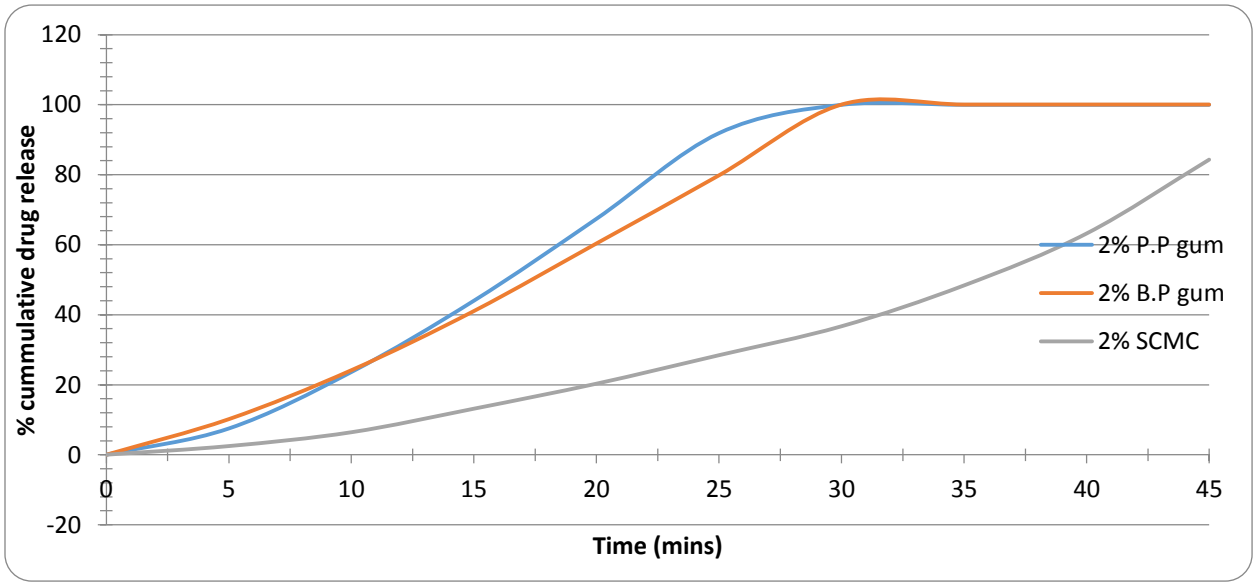


Figure 10:

***In vitro* dissolution test for paracetamol tablet formulated with 4% of the binders**

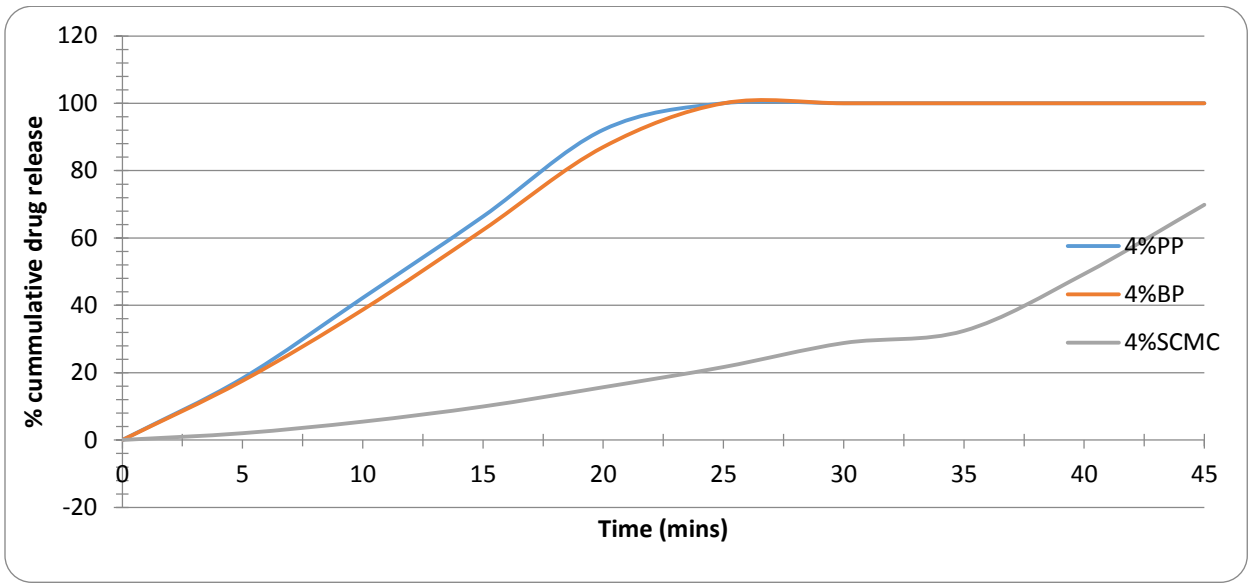


Figure 11:

***In vitro* dissolution test for paracetamol tablet formulated with 6% of the binders**

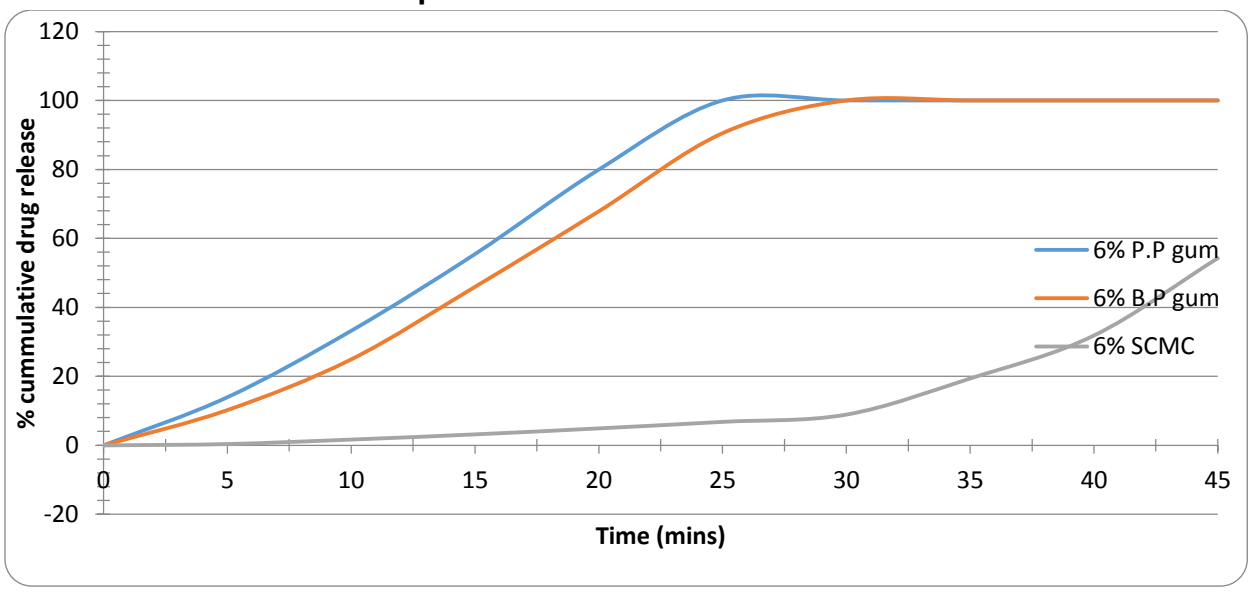


Figure 12:

***In vitro* dissolution test for Paracetamol tablet formulated with 8% of the binders**

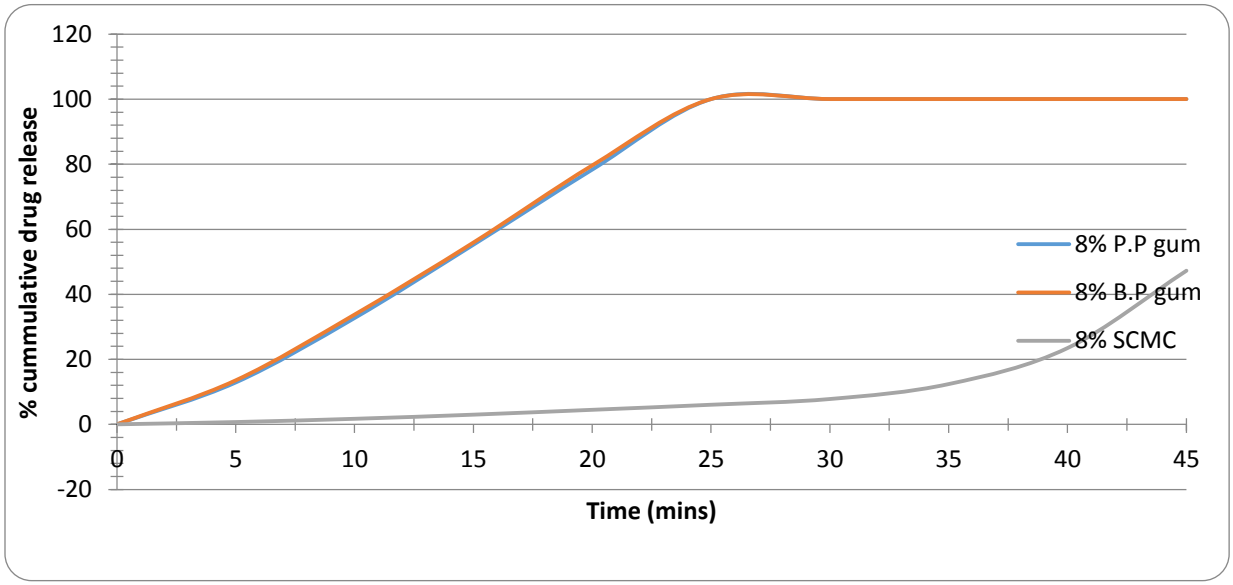


Figure 13:

***In vitro* dissolution test for paracetamol tablet formulated with 10% of the binders**

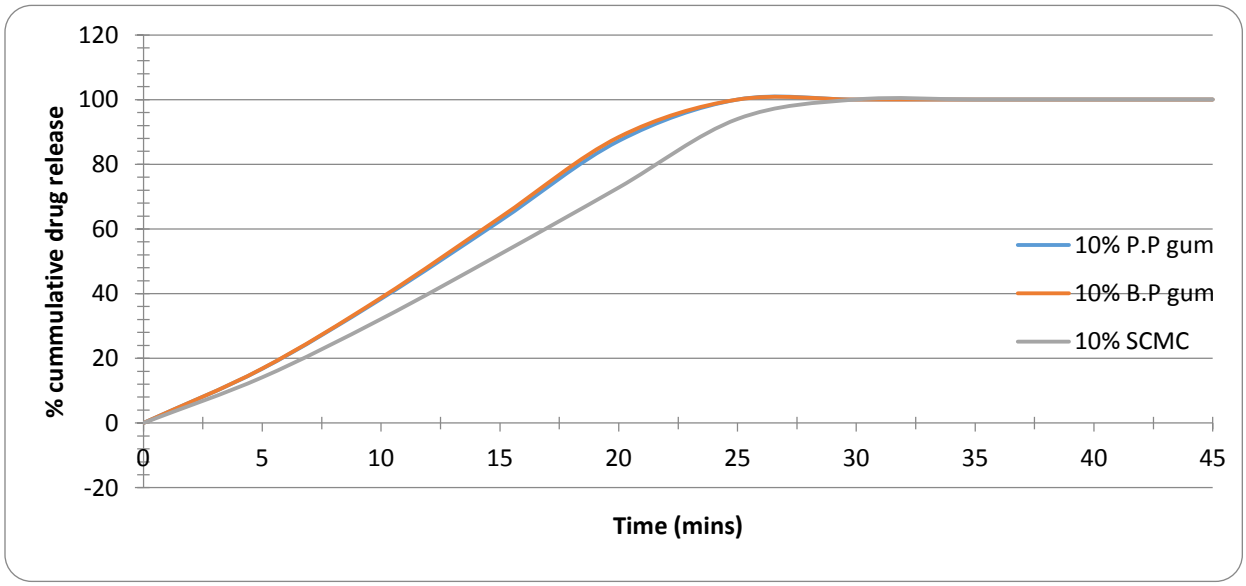


Table 9:

Post-Hoc test: Multiple comparisons for hardness test

Dunnett t (2-sided)[a]

Dependent Variable	(I) BatchH1	(J) BatchH1	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
						Lower Bound	Upper Bound
tabletH1	A1	C1	-1.95000*	.30246	.000	-2.8677	-1.0323
	B1	C1	.00000	.30246	1.000	-.9177	.9177
tabletH2	A1	C1	-3.58000*	.36602	.000	-4.6906	-2.4694
	B1	C1	-3.23000*	.36602	.000	-4.3406	-2.1194
tabletH3	A1	C1	-6.15000*	.71970	.000	-8.3337	-3.9663
	B1	C1	-6.05000*	.71970	.000	-8.2337	-3.8663
tabletH4	A1	C1	-7.39000*	.58682	.000	-9.1705	-5.6095
	B1	C1	-7.89000*	.58682	.000	-9.6705	-6.1095
tabletH5	A1	C1	.25000	.70042	.912	-1.8752	2.3752
	B1	C1	-.85000	.70042	.384	-2.9752	1.2752

**. The mean difference is significant at the 0.01 level.*

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

Table 10:

Paired Samples T-Test for hardness

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	99% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	AH1 - BH1	-1.95000	1.14139	.36094	-3.12300	-.77700	-5.403	9	.000
Pair 2	AH2 - BH2	-.35000	.52967	.16750	-.89434	.19434	-2.090	9	.066
Pair 3	AH3 - BH3	-.10000	.51640	.16330	-.63070	.43070	-.612	9	.555
Pair 4	AH4 - BH4	.50000	.81650	.25820	-.33910	1.33910	1.936	9	.085
Pair 5	AH5 - BH5	1.10000	1.33250	.42137	-.26939	2.46939	2.611	9	.028

Table 11:

Post-Hoc Test: Multiple Comparisons for Disintegration Time Test

Dunnett t (2-sided)[a]

Dependent Variable	(I) batchD1	(J) batchD1	Mean Difference (I-J)	Std. Error	Sig.	99% Confidence Interval	
						Lower Bound	Upper Bound
tabletD1	AD1	CD1	-921.16667*	.88192	.000	-924.0354	-918.2980
	BD1	CD1	-928.66667*	.88192	.000	-931.5354	-925.7980
tabletD2	AD1	CD1	-912.83333*	1.08355	.000	-916.3579	-909.3088
	BD1	CD1	-920.00000*	1.08355	.000	-923.5245	-916.4755
tabletD3	AD1	CD1	-934.16667*	1.59745	.000	-939.3628	-928.9705
	BD1	CD1	-931.50000*	1.59745	.000	-936.6962	-926.3038
tabletD4	AD1	CD1	-986.50000*	2.17817	.000	-993.5851	-979.4149
	BD1	CD1	-987.50000*	2.17817	.000	-994.5851	-980.4149
tabletD5	AD1	CD1	-902.00000*	2.22111	.000	-909.2248	-894.7752
	BD1	CD1	-909.00000*	2.22111	.000	-916.2248	-901.7752

**. The mean difference is significant at the 0.01 level.*

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

Table 12:

Paired Samples T-Test for Disintegration Time Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	99% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	AD1 - BD1	7.50000	1.76068	.71880	4.60171	10.39829	10.434	5	.000
Pair 2	AD2 - BD2	7.16667	1.72240	.70317	4.33140	10.00194	10.192	5	.000
Pair 3	AD3 - BD3	-2.66667	1.36626	.55777	-4.91569	-.41764	-4.781	5	.005
Pair 4	AD4 - BD4	1.00000	1.54919	.63246	-1.55015	3.55015	1.581	5	.175
Pair 5	AD5 - BD5	7.00000	2.00000	.81650	3.70777	10.29223	8.573	5	.000

Conclusion

The waste peel of *M. sapientum* was processed and employed as adhesive in paracetamol tablets. The properties evaluated compared favorably to those of SCMC which is semi-synthetic, as well as those of *M. acuminata* peel gum, which was also obtained from waste and previously shown to be a viable alternative to SCMC. The tablets made with *M. sapientum* have good hardness profile and very fast disintegration and dissolution, however, the tablets tend to be friable. In a future work, a mixture of *M. sapientum* peel gum and SCMC will be employed which is expected to reduce the friability caused by *M. sapientum* gum while reducing long disintegration and release time caused by SCMC.

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