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Research Article

# MECHANICAL AND TABLET COATING PROPERTIES OF CASHEW TREE (*ANACARDIUM OCCIDENTALE* L) GUM-BASED FILMS

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**ABSTRACT**

The mechanical and coating properties of cashew gum-based films, using paracetamol as a model drug, was investigated. Cashew gum was acidic and the acidity did not markedly change with concentration and storage time. However, gum viscosity increased significantly with concentration and storage time. Swelling index of the gum was ~ 3.3 and was largely unaffected by pH of media used. Free films of cashew gum, cashew gum/hydroxypropyl methylcellulose (HPMC), and cashew gum/ carboxymethyl cellulose (CMC) were prepared by solvent casting using glycerol as a plasticizer and the folding endurance, tensile strength, percentage elongation and Young's modulus of the films determined. Cashew gum films were smooth, uniform and transparent while cashew gum/HPMC and cashew gum/CMC films lacked uniformity and surface smoothness, respectively. Addition of a plasticizer to the gum imparted flexibility to the films. Increase in cashew gum and plasticizer concentration increased the folding endurance and percentage elongation of the films. Tensile strength increased with increase in gum concentration but decreased with increase in plasticizer concentration. Young's modulus decreased when cashew gum and plasticizer concentrations were increased. Film coating of 7.5 % w/v cashew gum formulation to paracetamol tablet cores enhanced the mechanical strength of the tablets. However, film coating of the tablet cores did not markedly affect disintegration and drug release properties of the tablets compared to the uncoated tablets. Also, no significant difference in drug release was observed in 0.1 M HCl (pH 1.5) and phosphate buffer pH 6.8 used. Cashew gum when applied at 7.5 % w/v could be useful as non-functional film coatings for conventional solid dosage forms.

**Keywords:** *Anacardium occidentale*, Cashew gum, film coating, mechanical properties of films, non-functional coating

## INTRODUCTION

Cashew tree gum is obtained as exudates from the stem bark of *Anacardium occidentale* L. (family: *Anacardiaceae*), a tree that grows in many tropical and subtropical countries [1, 2]. The gum has been studied extensively for potential pharmaceutical and biomedical applications [2 – 9] because it is naturally-occurring, generally non-toxic, widely available, hydrophilic, inexpensive, biocompatible and biodegradable. Quite recently, *Lippia sidoides* essential oil was successfully encapsulated in nanoparticles of cashew gum/chitosan polymeric matrix with the presence of the oil in the nanoparticles having been confirmed by FTIR and bioassays. The nanoparticles were demonstrably effective in killing the larvae of dengue vector in a sustained release manner [10]. Cashew gum prepared as layer by layer films were studied by atomic force microscopy and voltammetry and were found to detect dopamine in low concentrations. These layer by layer cashew gum films therefore have potential application in nanobiomedical devices as electrochemical sensors [11]. Cashew gum/carboxymethyl cellulose/glycerol composed films produced by casting have also been shown to have potential as materials for technological applications [12].

Natural gums and other polysaccharides such as cashew gum, amylose, chitosan, pectin, khaya gum and albizia gum are hydrophilic film formers and have been fabricated as film coatings for the pharmaceutical [13 – 16], food and packaging industries [1, 17, 18, 19]. Film coating of tablets can mask the bitter or unpleasant taste and odour, ease swallowing, as well as protect the tablet cores against moisture and light. Film coated tablets exhibits high mechanical strength which protects the integrity of the tablet cores during packaging and handling. Film-coated tablets may exhibit immediate-release (non-functional), modified-release (functional, e.g. enteric coating and extended release coating) and targeted drug delivery properties. The use of natural gums and other polysaccharide-based film coatings are also known to increase the shelf life of food products by eliminating or minimizing dehydration, rancidity and darkening of the food surface [1]. Polysaccharide-based films may act as barriers against water vapour and gases and enhance mechanical handling properties of foods [19].

The film-forming property of cashew gum is attributable to the good rheological properties and the chemical composition of the biopolymer . The gum is a complex polysaccharide with highly branched galactan framework of (1→3)-linked β–D-galactopyranosyl units interspersed with β-(1→ 6) linkages and is chemically composed of 61 % galactose, 14 % arabinose, 7 % rhamnose, 8 % glucose, 5 % glucuronic acid and < 2 % other sugar residues [7, 20] . The crude gum contains $Ca^{2+}$, $Mg^{2+}$, $Fe^{2+}$ and $Zn^{2+}$ and trace amounts of $K^+$ and $Na^+$ as neutralized cations, the level of which reduces after purification [8]. The presence of glucuronic acid (pKa ~ 3.5) enables cashew gum to behave as a polyanion at pH > 4 [21], which enhances its ability of interacting with cations.

The objective of this study was to evaluate the mechanical properties of cashew gum-based free films prepared by solvent casting, as well as the coating properties of the films on paracetamol tablet cores.

## MATERIALS AND METHODS

### Materials

Crude cashew tree gum (moisture content, 13.00 ± 2.83 %; insoluble matter, 0.40 ± 0.07 %,) was obtained from a cashew tree plantation at Nkoranza in the Ashanti Region of Ghana, as natural exudates from the stem bark of *Anacardium occidentale* Linn, family *Anacardiaceae*. The plant was authenticated and the gum collected and supplied by a retired officer of FORIG, Ghana. The crude gum was purified (percentage yield ~ 77 %) using a previously described procedure [8]. The purified cashew gum (moisture content, 11.20 ± 0.14 %; insoluble matter, 0.20 ± 0.03 %) was used for the study. Paracetamol powder BP, lactose and magnesium stearate were supplied by Kinapharma Ltd., Accra, Ghana. Maize starch, polyvinyl pyrrolidone (PVP), carboxymethyl cellulose were obtained from Tradewinds Chemists, Kumasi, Ghana, while talc and hydroxypropyl methylcellulose (HPMC E15, viscosity of 2% solution @ 15 cPs) were supplied by Amponsah-Effah Pharmaceuticals Ltd., Kumasi, Ghana. All other chemicals used in this study were of analytical reagent grade.

### Swelling capacity of purified cashew gum

The swelling capacity of purified cashew tree gum in three dispersion media, namely: distilled water, 0.1 M HCl (pH 1.5) and phosphate buffer pH 6.8 was determined using a previously reported method [22].

**Viscosity and pH of gum mucilage**

Purified cashew gum mucilage was prepared with distilled water at concentrations of 5, 10, 15 and 20 % w/v. The viscosity of the samples was determined weekly over a 6-week period at 25 °C and shear rate of 1 rpm using a Brookfield viscometer (spindle number 2) (Model DV-I+, PHYWE, Gottingen, Germany). The pH of the samples was also determined at weekly intervals for six weeks at 25 °C, using a standardised pH meter (Eutech Instuments, The Netherlands).

**Preparation of cashew gum-based free films**

Cashew gum-based free films were prepared by the solvent casting method. The components of the film formulations are shown in Table 1. For each formulation, the required amount of the polymer material (cashew gum alone, or cashew gum and CMC or HPMC) was weighed into a beaker and 15 ml of distilled water added. The mixture was stirred with a stirrer, plasticized with the required amount of glycerol or propylene glycol and then stirred again with a magnetic stirrer for 2 h. The solution was made up to the final volume (20 ml) with distilled water and then left to stand overnight to enhance dissolution and to remove any trapped air bubbles. The mixture was then stirred again for 1 h. The 20 ml formulation was then carefully poured into the centre of a 9 cm diameter plastic Petri dish and then left to dry in an oven at 60 °C . The drying times of the films varied from 4 to 6 h. The films were then carefully removed and placed in labeled Petri dishes which were stored in a dessicator for further evaluation.

**Measurement of film thickness**

The thickness of the films (1 × 1 cm) was determined at five different locations (centre and four peripheral locations) using a micrometer (Clarke Instruments Ltd., Salisbury, UK) and a mean value and the standard deviation of the five measurements was calculated.

**Folding endurance of films**

A strip of film (2 x 2 cm) of each formulation was cut by using a sharp scissors. Folding endurance was determined by repeatedly folding the film at the same place. The number of times the film could be folded at the same place without breaking gave the value of folding endurance. The experiment was repeated twice and the mean folding endurance determined.

**Table 1: Details of the cashew gum-based film formulations**

| Material | Film formulation | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 | F10 | F11 | F12 |
| Conc. of cashew gum(% w/v) | 7.5 | 10.0 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 10.0 | 10.0 | 10.0 | 12.5 |
| Weight of cashew gum (g) | 1.5 | 2.0 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.0 | 2.0 | 2.0 | 2.0 |
| Weight of 1 % w/v CMC (g) | - | - | - | - | - | - | - | - | 0.20 | - | - | - |
| Weight of 2 % w/v CMC (g) | - | - | - | - | - | - | - | - | - | 0.40 | - | - |
| Weight of 1% w/v HPMC (g) | - | - | - | - | - | - | - | - | - | - | 0.20 | - |
| Weight of 2% w/v HPMC (g) | - | - | - | - | - | - | - | - | - | - | - | 0.40 |
| Conc. of plasticizer(% w/w) (related to total polymer content) | 20 | 20 | 20 | 0 | 5 | 10 | 20 | 30 | 20 | 20 | 20 | 20 |
| Weight of plasticizer (g) | 0.3 | 0.4 | 0.5 | 0 | 0.125 | 0.25 | 0.50 | 0.75 | 0.44 | 0.48 | 0.44 | 0.48 |
| Water to (ml) | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |

**Mechanical properties of films**

The tensile strength, percentage elongation and Young's modulus of the cashew gum-based free films were evaluated using a Hounsfield Universal Testing Machine (Hounsfield Ltd., Surrey, UK) with a 500 N load cell. Film strips of dimensions 5 × 1 cm free from air bubbles or physical imperfections were held between two clamps positioned at a distance of 3 cm. During measurement, the strips were pulled by the top clamp at a rate of 100 mm/min until the force applied was sufficient to break each film. The force at break and elongation were then recorded. The determinations were done in triplicate for each formulation. Three parameters of the free films, namely tensile strength, Young's modulus and percent elongation were calculated using the following equations:

$$\text{Tensile strength} = \frac{\text{Force at break (N)}}{\text{Initial cross-sectional area of the sample (mm}^2\text{)}} \quad (\text{N/ mm}^2)$$

$$\% \text{ elongation} = \frac{\text{Increase in length of film}}{\text{Original length of film}} \times 100$$

$$\text{Young's modulus} = \frac{\text{Force at break (N)}}{\text{Change in length}} \times \frac{\text{Original length of film}}{\text{Cross-sectional area of film}} \quad (\text{N/ mm}^2)$$

**Preparation of tablets**

Granules comprising of paracetamol (62.5 % w/w), lactose (25.2 % w/w), maize starch (8.0 % w/w), PVP (2.5 % w/w), talc (1.5 % w/w) and magnesium stearate (0.3 % w/w) were prepared by the wet granulation method. Paracetamol, lactose and maize starch were weighed and dry-mixed by geometric dilution in a clean porcelain mortar and massed with 10 % w/v PVP mucilage. The damp mass was screened through sieve number 8 and the granules dried at 60 °C for 1 h in a hot air oven. The dried granules were then screened using sieve number 16 and lubricated with talc and magnesium stearate. The granules were dried again at 60 °C for 5 min in a hot air oven and compressed into tablets with a nominal weight of 400 mg (< 2 tablets ± 5 % average weight, none ± 10 % average weight, *n = 20*) using a lubricated Single punch tabletting machine (DP30 tablet press, Pharmao Industries Co. Ltd., China) fitted with a concave punch and die set. Tablets with average crown thickness of 5.82 ± 0.06 mg (Micrometer, Clarke Instruments Ltd., Salisbury, UK), friability of 0.47 % (Erweka Friabilator, TA 20 GmbH, Heusenstamm, Germany), hardness of 3.6 kp (*n = 20*) tested with a Monsanto hardness tester (Missouri, USA), diameter ~ 10 mm were produced and stored in plastic containers until use.

**Assay of tablets**

Twenty (20) uncoated paracetamol tablets were randomly selected, weighed and powdered. A quantity of the powder containing 0.15 g of paracetamol was added to 50 ml of 0.1M NaOH. This was then diluted with 100 ml distilled water, shaken for 15 min and sufficient water added to produce 200 ml of solution. The solution was further shaken and filtered through 0.45 µm HA membrane filter, and 10 ml of the filtrate was taken and diluted to 100 ml with distilled water. Ten (10) ml of the resulting solution was taken and added 10 ml 0.1M NaOH and the solution diluted to 100 ml with water. The absorbance of this final solution was measured at 257 nm by UV spectrophotometer (PG Instruments Ltd., Leicestershire, UK), using 0.1M NaOH as the reference solution.

Using the regression data ($y = 702.9x + 0.524$, $R^2 = 0.999$) obtained from a calibration plot of paracetamol powder (0.25 – 1.5 mg/ml) in 0.1 M NaOH, the amount of paracetamol in the tablets was calculated.

**Film coating process**

A Manesty tablet coater fitted with a sprayer (Manesty Ltd., Huddersfield, UK) rotating at a speed of 25 revs/min was used for the film coating process. The equipment was switched on to allow the drying air to reach a temperature of 60 °C. One hundred and fifty (150) tablets of paracetamol were loaded into the pan coater and pre-warmed for five (5) min while the tablets tumbled. As the tablets rolled, the nozzle of the pumping device was directed at the centre of the disc and a 7.5 % w/v cashew gum coating solution plasticized with glycerol (20 % w/w related to dry gum content) was sprayed intermittently, allowing the solvent to evaporate. A cycle of 30 s of spraying (6 sprays) followed by five (5) min of drying was employed. The tablets were stirred during the drying periods to prevent gross agglomeration. The cycle was repeated eight (8) and sixteen (16) times to obtain two batches of tablets having coating times of four (4) and eight (8) min respectively. Other process parameters used to coat the tablets were: spray rate of pump (48.3 ± 0.6 ml/min), temperature of drying air (60 °C), distance of spray pump from pan (13 cm), and spray gun nozzle diameter (1 cm). The coated tablets having % weight gain: 4 min coated, 0.46 % w/w, 8 min coated, 1.94 % w/w; average crown thickness: 4 min coated, 5.82 ± 0.06 mm, 8 min coated, 5.85 ± 0.06 mm; hardness: 4 min coated, 7.1 ± 1.4 kp, 8 min coated, 8.8 ± 1.2 kp, were placed in glass Petri dishes and dried in a hot air oven at 40 °C overnight.

**Disintegration of tablets**

Disintegration tests on uncoated and film-coated tablets were carried out at 37 ± 2 °C with an Erweka disintegration apparatus (ZT3, GmbH, Heusenstam, Germany) using an official method [23]. The disintegration media used were distilled water, 0.1 M HCl and phosphate buffer pH 6.8.

***In vitro* drug release studies**

Drug release studies were carried out on the uncoated and film-coated tablets using an Erweka Dissolution machine (Type DT6, Heusenstamm, Germany) (paddle method). The dissolution parameters used: 37 ± 0.5 °C; 50 rpm; 900 ml dissolution media. The dissolution media used were 0.1 M HCl (pH 1.5) and phosphate buffer pH 6.8. At specified time intervals of 5, 10, 15, 20, 30, 45, 60 and 90 min, 5 ml samples were withdrawn and replaced with equal amount of fresh dissolution medium. The withdrawn samples were filtered through 0.45 µm HA membrane filters and diluted appropriately with the dissolution medium. The diluted filtrates were analysed by UV spectrophotometer (PG Instruments Ltd., Leicestershire, UK) for paracetamol at a wavelength of 257 nm with the use of regression data (0.1 M HCl: $y = 540.6x + 0.019$, $R^2 = 0.998$; phosphate buffer pH 6.8: $y = 488.1x - 0.003$, $R^2 = 0.992$) obtained from calibration plots of paracetamol in the two media (0.25 – 1.5 mg/100 ml). From these, plots of percentage paracetamol released from the tablets (mean ± S.D., *n = 3*) against time were established.

**Statistical analysis**

GraphPad Prism 5 (GraphPad Software, Inc., USA) was used to perform statistical tests on data. Analysis of variance followed by Bonferroni test was used to determine differences among samples tested. Differences were considered significant when $p < 0.05$.

**RESULTS AND DISCUSSION**

Figure 1 shows photographs of crude and purified cashew tree gums. Crude cashew gum was golden brown in colour while purified cashew gum (yield ~ 77 %) was off-white to buff coloured. Table 2 shows the swelling capacity of purified cashew gum in different media. The swelling capacity varied from 3.29 – 3.83 and followed the order: distilled water < 0.1M HCl < phosphate buffer pH 6.8 ($p > 0.05$). The swelling capacity of cashew gum in distilled water (~ 3.3) was lower than that reported for *Khaya senegalensis* gum (10) [24], tragacanth gum (13.63) and *Delonix regia* seed gum (17.84) [25], but higher than that of *Acacia sieberiania* gum (2.0) [26]. The swelling capacity of a polymer provides an indication of the level of hydration and hence the hydrophilic character of the polymer. In general, a polymer material with a high swelling capacity will produce longer disintegration and dissolution times when employed as film or compression coatings for tablets and multiparticulates. This is because the polymer will swell in the disintegration/dissolution medium to form a gelatinous gel around the tablet cores which consequently slows down the capillary flow of liquid into the tablets and also increases the diffusion path length of drug molecules.

**Table 2: Swelling capacity of purified cashew gum in different media**

| Medium | Swelling capacity |
|---|---|
| Distilled water | 3.29 ± 0.02 |
| 0.1 M HCl | 3.53 ± 0.06 |
| Phosphate buffer pH 6.8 | 3.83 ± 0.12 |

A B

**Fig. 1: Crude and purified cashew tree gum. Grade of gum: A = crude cashew gum; B = purified cashew gum**

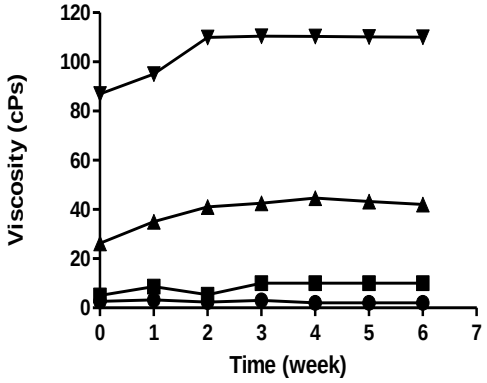


**Fig. 2: Effect of concentration and storage time on the viscosity of purified cashew gum mucilage at 25 °C. Concentration of gum: ● = 5 % w/v; ■ = 10 % w/v; ▲= 15 % w/v; ▼= 20 % w/v**

Figure 2 shows the effect of concentration and storage time on viscosity of purified cashew gum mucilage. The viscosity of the gum increased significantly ($p < 0.05$) with increase in concentration from 10 to 20 % w/v. However, no marked increase in viscosity ($p > 0.05$) was observed when gum concentration was increased from 5 to 10 % w/v. Unlike other gums like guar, and tragacanth which have viscosities > 10 cPs at concentrations as low as 1% w/v, the viscosity of 5 % w/v cashew gum was ~ 2.7 cPs. Being a low viscosity polymer, cashew gum is suitable for film coating of pharmaceutical dosage forms as high viscosity can be attained by increasing the solid content in the coating formulation. There was a gradual increase in viscosity in the first two weeks of storage for 15 and 20 % w/v cashew gum mucilage, after which the viscosities remained fairly constant. The increase in viscosity observed could be due to hydration of the gums resulting in an increase in gum volume. At 5 – 10 % w/v concentration, cashew gum had fairly constant viscosities with increase in storage time.

The purified cashew gum mucilage was acidic (Fig. 3), confirming the findings of previous studies of the gum [8, 27]. The acidity of the gums could be attributed to the acidic functional group (uronic acid) of sugar units in the gum. The pH of 5 – 20 % w/v freshly prepared gum mucilage ranged from 4.28 - 4.44. High concentrations of the gum mucilage were slightly more acidic ($p > 0.05$) than low concentration ones, probably due to higher contents of uronic acid units in the concentrated preparations. No marked change in pH of the samples ($p > 0.05$) was observed after storage at room temperature over a six-week period. The slight reduction in pH observed in the first four weeks of storage of the samples could be attributed to fermentation of the sugar units and the gradual hydrolysis of uronic acid units making the solutions more acidic.

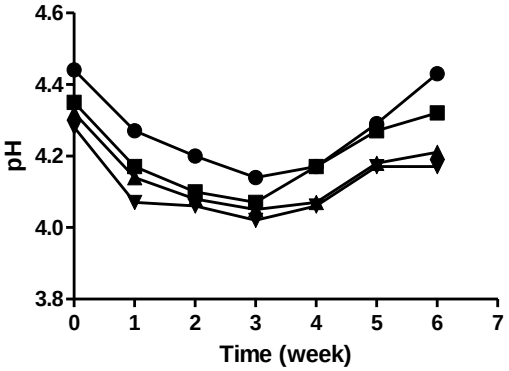


**Fig. 3: Effect of concentration and storage time on the pH of purified cashew gum mucilage at 25 °C. Concentration of gum: ● = 5 % w/v; ■ = 10 % w/v; ▲= 15 % w/v; ▼= 20 % w/v**

Films plasticized with propylene glycol were transparent, but exhibited intense folding, the level of which increased as the concentration of the plasticiser increased (data not shown). Propylene glycol was therefore deemed an unsuitable plasticiser for cashew gum films. It is desirable for plasticizers to be compatible with the polymer material in order to produce films having the requisite appearance and physical properties [28]. Films containing cashew gum alone (F1 – F8) were uniform, transparent and had smooth surfaces, while cashew gum/CMC films (F9 & F10) were rough to touch, uniform and quite opaque, but were easily removable from the Petri dishes they were cast. A previous study has shown that a combination of cashew gum and CMC increases the hydrophobic properties of the resultant cashew gum/CMC films [12]. Cashew gum/HPMC films (F11 & F12) were not uniform in appearance, with slightly rough surfaces, and thus appeared incompatible possibly as a result of repulsive interactions between them. A chemical (acid or alkaline hydrolysis) or enzymatic modification of cashew gum may enhance the properties of the films and also make the gum more suitable for blending with other polymeric materials. Films containing 0 – 5 % w/w (related to total polymer content) glycerol or propylene glycol (F4 & F5) were very brittle due to absence or insufficient amount of plasticizer. Plasticizers are known to enhance the film-forming characteristics of polymer materials by interposing themselves between the polymer chains. This modifies the forces that hold the polymer chains together leading to the extension and softening of the polymer film

[29]. Low or insufficient plasticizer in film formulations will therefore result in poorly extended and hard films which are brittle in nature.

Table 3 shows the mechanical properties of glycerol-plasticized cashew gum-based films. The mechanical properties of free films are measured to ascertain the strength and deformation characteristics of the films. The folding endurance of a film is used to characterize the ability of the film to withstand repeated bending, folding, and creasing and may be used as a measure of film quality. The folding endurance observed in the current study varied among the different film formulations and ranged from 98 to > 400. The folding endurance increased with increase in plasticizer concentration, thereby producing films with elastic properties. This is because plasticizers reduce brittleness; impart flexibility, increase toughness, and increase the tear resistance of a film. The results indicated that the films would not crack and can maintain their integrity with moderate to quite frequent folding or handling. A folding endurance of up to 300 is considered satisfactory to reveal good film properties [30]. An increase in CMC concentration of cashew gum/CMC films from 1 % to 2 % almost doubled the folding endurance, tensile strength and Young's modulus, while elongation at break remained almost unchanged.

**Table 3: Film thickness and mechanical properties of cashew gum-based free films plasticized with glycerol**

| Film Formulation | Film thickness (mm) | Folding endurance | Tensile strength (MPa) | Elongation at break (%) | Young's modulus (MPa) |
|---|---|---|---|---|---|
| F1 | 0.21 ± 0.01 | 289 | 0.56 ± 0.04 | 54.34 ± 9.45 | 1.03 ± 0.11 |
| F2 | 0.24 ± 0.00 | 299 | 0.65 ± 0.05 | 65.88 ± 2.33 | 0.98 ± 0.06 |
| F3 | 0.26 ± 0.01 | 249 | 0.71 ± 0.03 | 84.53 ± 4.89 | 0.81 ± 0.08 |
| F4 | ND | ND | ND | ND | ND |
| F5 | 0.32 ± 0.01 | ND | ND | ND | ND |
| F6 | 0.31 ± 0.00 | 98 | 3.62 ± 0.38 | 41.85 ± 9.72 | 8.98 ± 2.32 |
| F7 | 0.26 ± 0.01 | 249 | 0.71 ± 0.03 | 84.53 ± 4.89 | 0.81 ± 0.08 |
| F8 | 0.29 ± 0.01 | 356 | 0.47 ± 0.08 | 89.09 ± 7.42 | 0.58 ± 0.07 |
| F9 | 0.31 ± 0.00 | 210 | 1.53 ± 0.11 | 76.39 ± 6.48 | 2.32 ± 0.58 |
| F10 | 0.32 ± 0.01 | > 400 | 4.44 ± 0.24 | 80.01 ± 4.70 | 5.57 ± 0.63 |
| F11 | ND* | ND* | ND* | ND* | ND* |
| F12 | ND* | ND* | ND* | ND* | ND* |

**ND = Not determined due to brittleness of film**
**ND* = Not determined due to lack of uniformity of film**

A soft and weak polymer has low tensile strength and low elongation while a hard and brittle polymer exhibits moderate tensile strength and low elongation. On the other hand, a soft and tough polymer has moderate tensile strength and high elongation, whereas a hard and tough polymer is characterized by high tensile strength and high elongation [31]. The percentage elongation (elongation at break), which is a measure of the capacity of the films to deform, increased with increase in both cashew gum and plasticizer concentration. This is because, the more flexible a film is; the longer it can be stretched before tearing. Lower elongation indicates a low deformation capacity of the film and a brittle film structure. A plasticizer will decrease the interaction forces between adjacent polymeric chains and increase chain mobility, thereby making the film more flexible [1].

Tensile strength of the films increased as cashew gum concentration increased but decreased with an increase in plasticizer concentration. Plasticizers increase film flexibility, thus making the films less tough, with lower tensile strength. A recent study using Pareto bar charts to analyse the tensile strength data of cashew gum films reported that cashew gum concentration is the most important factor which influences the tensile strength of the films [1]. Increasing the cashew gum and plasticizer content decreased Young's modulus of the films, however, a low Young's modulus value contributes to an increase in the adhesion between the film and the tablet coating surface [32]. All the films had quite low tensile strength values, ranging from 0.47 – 4.44 MPa. The low tensile strength values would suggest the risk of film cracking but no sign of cracking in the free films occurred due possibly to the lower Young's modulus of the films. A similar study reported low tensile strength values of 0.32 – 0.49 MPa for rosin-based biomaterials but no film cracking was observed due to the low elastic modulus of the films [33]. On the whole, the cashew gum-based free films possessed a good balance of folding endurance, tensile strength, % elongation and Young's modulus.

Film formulation 1 containing cashew gum only (7.5 % w/v) plasticized with glycerol was selected for coating paracetamol tablet cores (mean content: ~ 97 %) as it had reasonable values for the mechanical properties determined. The film coated tablets were generally good looking with smooth coats and no coating defects, and a rub against a white paper did not reveal any peel (Fig. 4). The coated tablets had enhanced breaking strength and zero friability, indicating that the coating procedure improved the stress resistance of the tablets. The tablets had uniform weights and the increase in weight of the tablets after coating for four (4) and eight (8) min were 0.46 % w/w and 1.94 % w/w, respectively. Recently, multiparticulate pellets loaded with diltiazem hydrochloride were also successfully coated with uniform and continuous cashew gum films which are intended for controlled drug delivery [34].

**Table 4: Disintegration times of uncoated and cashew gum film-coated paracetamol tablets in different media**

| Type of tablet | Disintegration time (min) | | |
|---|---|---|---|
| | Distilled water | 0.1 M HCl | Phosphate buffer pH 6.8 |
| Uncoated | 1.1 ± 0.1 | 1.0± 0.1 | 0.5 ± 0.1 |
| Coated (4 min) | 2.5 ± 0.2 | 2.3 ± 0.3 | 2.3 ± 0.1 |
| Coated(8min) | 3.3 ± 0.6 | 2.6 ± 0.2 | 3.1 ± 0.4 |

Table 4 shows the disintegration times of the uncoated and coated tablets in various media. All the three batches of tablets disintegrated in < 5 min in the different media used and are within the accepted criteria of disintegration for uncoated and immediate-release coated tablets [23]. The uncoated tablets had the least disintegration times in the three media used, followed by the coated tablets (4 min) and then the coated tablets (8 min) ($p > 0.05$). Differences in pH of media used appeared to have little effect ($p > 0.05$) on tablet disintegration.

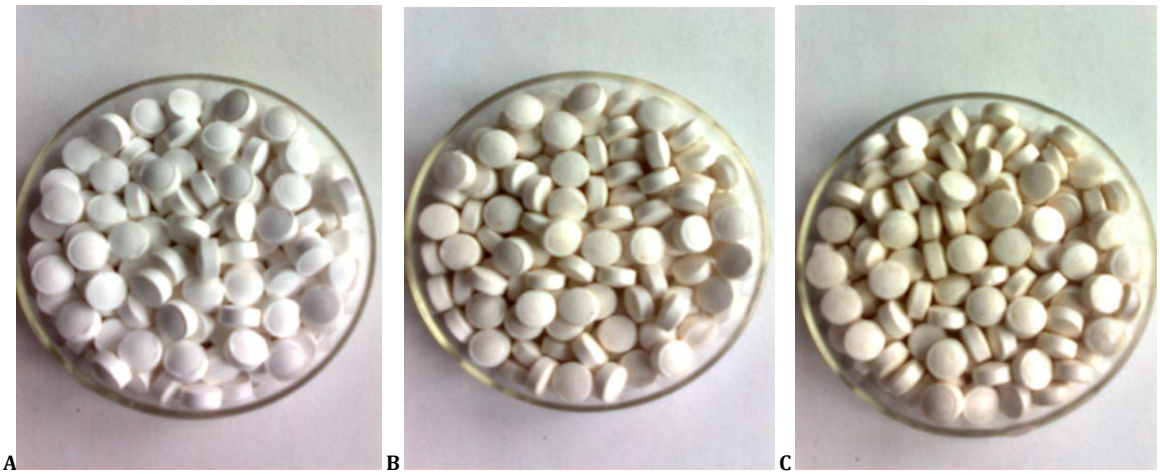

**Fig. 4: Photographs of the uncoated and cashew gum film-coated paracetamol tablets. Type of tablet: A = uncoated tablets; B = coated tablets (4 min); C = coated tablets (8 min)**

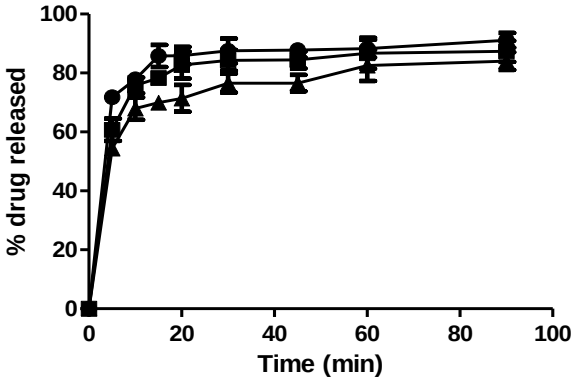


**Fig. 5: Release of paracetamol from uncoated and cashew gum film-coated tablets in 0.1 M HCl (mean ± S.D., n = 3). Type of tablet: ● = uncoated tablets; ■ = coated tablets (4 min); ▲ = coated tablets (8 min)**

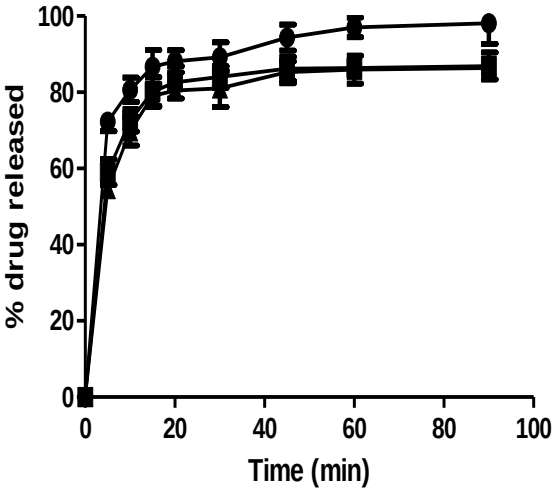


**Fig. 6: Release of paracetamol from uncoated and cashew gum film-coated tablets in phosphate buffer pH 6.8 (mean ± S.D., n = 3). Type of tablet: ● = uncoated tablets; ■ = coated tablets (4 min); ▲ = coated tablets (8 min)**

Figures 5 and 6 shows the drug release profiles of the uncoated and film-coated paracetamol tablets in 0.1 M HCl and phosphate buffer pH 6.8, respectively. Officially, at least 75 % of the active ingredient should be released from the tablets within 45 minutes of the dissolution test [23]. However, within 30 min, all the three tablet formulations had achieved this level of drug release in the two dissolution media used. There was no significant difference ($p > 0.05$) in the rates of drug release from the uncoated and coated tablets and no marked difference in drug release was observed in the two media used ($p > 0.05$). Thus, cashew gum being a hydrophilic gum had weak water resistance hence the similarity of the drug release profiles of the uncoated and the coated tablets. In a dissolution medium, the film coatings become easily hydrated, forming a gelatinous gel around the tablet cores. This gel undergo rapid erosion and/or dissolution which eventually expose the tablet cores to the media, enabling drug release to occur by diffusion at rates comparable to that of the uncoated tablets. Film coating of the tablets did not have a modifying effect on the release profiles and other biopharmaceutical properties of the active pharmaceutical ingredient. However, bitter or unpleasant taste and obnoxious odours could be effectively masked, swallowing can be eased and mechanical integrity of tablet cores could be improved without bioavailability being reduced, when cashew gum is used as a film coating agent for immediate-release or conventional tablets at a concentration of 7.5 % w/v, compared to the uncoated tablets. A previous study showed that HPMC at 7 % w/w was suitable for film coating paracetamol tablet cores intended for non-functional coating [35].

## CONCLUSIONS

This study has demonstrated that cashew gum-based films have the requisite mechanical and adhesion properties needed for successful tablet coating. Glycerol is a better plasticizer for cashew gum-based films than propylene glycol. Cashew gum (7.5 % w/v) plasticized with glycerol, when applied as films on a model drug, paracetamol, did not modify the release and other biopharmaceutical properties of the drug hence acting as non-functional coating. Cashew gum films could therefore be useful in coating immediate-release or conventional solid dosage forms to mask unpleasant taste and odour, ease swallowing, enhance mechanical properties and protect the dosage form against extreme environmental conditions.

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