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Research Article

Evaluation of Khaya gum (*Khaya senegalensis*) as a polymer in the formulation of floating *in situ* gels of metoprolol succinate

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ABSTRACT

Metoprolol succinate, a β-selective adrenergic blocker, has a short half-life, low bioavailability, and high dosing frequency. *In-situ* gel drug delivery is a good approach to achieve sustained release for once-daily administration that will prolong drug retention time at the stomach and increase absorption. Thus, the aim of the study is to formulate floating *in-situ* gel formulations of metoprolol succinate using Khaya gum (*Khaya senegalensis*, family *Meliaceae*) as a polymer. Khaya gum was characterized and used in formulating i*n situ* gels of metoprolol succinate in comparison with Hydroxyl Propyl Methyl Cellulose (HPMC K15M) and Xanthan gum. The *in-situ* gel formulations were characterized for appearance, swelling, *in-vitro* buoyancy and *in-vitro* drug release. FTIR revealed major peaks characteristic of the gum. Khaya gum showed high swelling and good flow properties. *In-situ* gel formulations of metoprolol succinate containing Khaya were light brown with near neutral pH, higher swelling and a total floating time >24 h, comparable to those containing HPMC and Xanthan gums. Dissolution time t_{80} was 60.50 to >240 min with ranking Khaya <HPMC <Xanthan. Khaya gum provides a cheaper, suitable polymer for formulating floating *in-situ* gels with prolonged buoyancy and drug release.

INTRODUCTION

Floating oral *in situ* gels are formulations applied as a solution, that undergoes gelation after instillation due to physicochemical changes inherent to the biological fluids (Vigani et al, 2020). An *in-situ* gel drug delivery is a novel idea of delivering drugs as a liquid dosage while achieving sustained release of drug. This is a solution of polymer with low viscosity, which changes polymeric conformation when it comes in contact with the gastric fluids and forms a strong viscous gel with a density lower than the gastric fluids (Chavan and Vyas, 2017; Tenci et al, 2019). The gelation can be triggered by pH change, temperature modulation and ionic cross-linking. In addition to the commonly administered oral route, *in situ* gels can be administered by vaginal, injectable, ocular, intraperitoneal and rectal routes (Padhan *et al*, 2019). Both synthetic and natural polymers have been used in the formulation of floating drug delivery systems. These gastroprotective floating systems are designed to be retained in the stomach for a prolonged period of time and release their active ingredients in a controlled manner, thereby enabling sustained and prolonged retention of the drug to the upper part of the gastrointestinal tract. Prolonged gastric retention time in the stomach provides many benefits which includes increase in duration of drug release, increase in solubility of drugs that are less soluble in elevated pH medium, improved bioavailability, reduced dose and side effects of drug, improved therapy, and patient compliance.

Natural polymers that are used include xanthan gum, sodium alginate, guar gum, chitosan, gellan gum, etc. On the other hand, some synthetic polymers that have been used for floating drug delivery include HPMC, Eudragit® RL, E and RS grades (derivatives of acrylic and methacrylic acids), ethyl cellulose, etc. Natural gums (mainly obtained from plants) are hydrophilic

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carbohydrate polymer of high molecular weight and are generally insoluble in organic solvents like hydrocarbon and ether. Many ion-sensitive polysaccharides such as sodium alginate, carrageenan, gellan gum (Gelrite®) and pectin undergo a phase transition in the presence of various ions such as K^+, Ca^{2+}, Mg^{2+}, Na^+. The gelling of this *in situ* gel system can be achieved by using polymer solutions such as sodium alginate triggered by ionic complexation that contains divalent-ions complexed with sodium citrate which breakdown in the acidic environment of the stomach to release free divalent ions (Ca^{2+}) due to change in pH (Mohanty *et al*, 2018). The free Ca^{2+} ions get entrapped in polymeric chains thereby causing cross-linking of polymer chains to form matrix structure causing the *in-situ* gelation. While the system is floating in the stomach, the drug is released slowly at the desired rate from the system. The residual system is emptied from the stomach after the release of the drug (Mohanty *et al*, 2018).

Khaya gum, an under-utilized gum obtained from the bark exudate of *Khaya senegalensis* (family Meliaceae), has been evaluated as a potential carrier for controlled delivery (Fell, 2004; Eichie and Amalime 2007; Odeku *et al*, 2014). The ability of Khaya gum to swell about ten times its original weight serves as an indicator for its use as a natural polymer in controlled release formulations and its potential as a polymer in floating drug delivery system (Mahmud *et al*., 2008).

Metoprolol succinate is a β-selective adrenergic blocking agent. The half-life of the drug is about 3-4 h and conventional dosage forms of the drug fail to maintain the drug plasma concentration over the extended period of time, leading to frequent dosing (Huang *et al*, 2005). These make the drug a suitable candidate for the development of a sustained-release formulations such as *in situ* gel formulations. In this study, metoprolol succinate was formulated as floating *in situ* gel in order to sustain the release of the drug. In the formulations of *in situ* gels prepared, polymer blend of sodium alginate and Khaya gum were used as gel-forming polymer and calcium carbonate as a cross linking agent and gas-generating agent while hydroxy polymethyl cellulose (HPMC K15M 2208) and Xanthan gum were the standards.

MATERIALS AND METHODS

Materials

The materials used were Ethanol (Sigma-Aldrich GmbH), Metoprolol Succinate (Xi'an Sgonek Biological Technology Co. Ltd, Xi'an City, China), Sodium alginate E401 mol. wt. 1.93 X 10^5g/mol and Xanthan gum E415 mol. wt. 933.748g/mol (Special Ingredient Limited, Foxwood Industrial Park Chesterfield S41 9RN UK.). HPMC K15M was from Oxford Lab Chemicals, Maharashtra, India. Khaya gum was obtained from the incised trunks of *Khaya senegalensis* from the Botanical Garden, University of Ibadan.

Methods

Extraction of gum

Khaya gum was obtained from the cut bark of *Khaya senegalensis* (family Meliaceae). The barks were soaked in chloroform water for 48 hours to allow the gum to diffuse out of the bark. The gum was strained through a muslin cloth to remove extraneous materials and then precipitated using absolute ethanol, washed with diethyl ether followed by drying in hot air oven at 50^0C for 48 hours. The dried gum was pulverized and then passed through a sieve of size 0.25mm.

Characterization of gum

Morphology

The morphology of the gum powder was observed using a scanning electron microscope (Hitachi SU8030 FE-SEM Tokyo, Japan) at an accelerating potential of 10.0kV. All samples were super coated with gold prior to examination.

Fourier transform Infrared (FTIR) analysis

Khaya gum sample, sodium alginate and a 2:1 blend of both gums were analyzed for compatibility by FTIR (FTIR- Buckscientific, M530 model, USA) in transmission mode. The transmission spectra were recorded using at least 64 scans with 8cm^{-1} resolution in the spectral range 4000 - 400cm^{-1}.

Swelling index

Gum powder (10g) was placed into a 100 - mL measuring cylinder and the volume occupied was noted (V_1). 0.1N HCl solution (90 mL) was added to form a dispersion that was shaken for 2 min and then made up to volume. The slurry was allowed to stand for 24 h before the sedimentation volume was read (V_2). Percentage swelling was determined from the percent change in volume of the gum after swelling in comparison to its initial volume.

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pH determination

The pH of a 1% w/v aqueous solution of Khaya gum was determined using a pH meter (Model 720A, Thermo Electron Corporation, MA, USA).

Particle density

A 50-mL pycnometer was weighed empty (W), filled with the non-solvent (xylene) and the excess wiped off. The weight of the pycnometer with the non-solvent was determined (W_1). The difference in weight was calculated as W_2. A 2g quantity of the sample was weighed (W_3) and quantitatively transferred into the pycnometer bottle. The excess non-solvent was wiped off the pycnometer and weighed again (W_4). The particle density was calculated from the equation:

$$\frac{W2.W3}{50\ (W3 - W4 + W2 + W)gcm - 3} \quad (1)$$

Bulk density

The bulk density of the gum powder at zero pressure (loose density) was determined by pouring 10g of powder at an angle of 45° through a funnel into a glass measuring cylinder with a volume of 50mL. The bulk density was measured as the ratio of mass to volume occupied by the gum powder. Determinations were done in triplicate.

Tapped density

The tapped density was measured by applying 100 taps to 10g of sample in a graduated cylinder at a standardized rate of 30 taps per min. Determinations were done in triplicate.

Flowability

The flowability of the gums was evaluated using the Hausner's ratio and Carr's index:

$$\text{Hausner's ratio} = \frac{\text{Tapped density}}{\text{Bulk density}} \quad (2)$$

$$\text{Carr'sIndex} = \frac{(\text{Tapped density} - \text{Bulk density})}{\text{Tapped density}} \text{ x } 100 \quad (3)$$

Angle of repose

An open-ended cylinder was placed on a base of similar diameter. Sample (5g) was allowed to flow freely through a funnel under gravity, to form a conical heap. The angle of repose was calculated from:

$$\text{Tan } \theta = h/r \quad (4)$$

where h is the height of the powder and r is the radius of the base of the cone. The angle of repose was calculated from the mean of three determinations.

Viscosity

The viscosity of an aqueous dispersion of the gum (1%w/v) was determined using the Brookfield rheometer (DV-11+ pro model, Brookfield Engineering, USA) with spindle no. 3 and 4 at 50 and 100 rpm.

Preparation of *in situ* gel formulations of metoprolol succinate

Solution of Khaya gum-sodium alginate blend (as well as HPMC-sodium alginate and Xanthan gum-sodium alginate blends) at various ratios of gum: alginate were made in deionized water (in which 0.25% w/v sodium citrate was previously dissolved). The solution was heated to 60°C with constant stirring on a magnetic stirrer. It was then allowed to cool to 40°C and calcium carbonate (0.5g) was added with continuous stirring. Metoprolol succinate (2g) and aspartame (0.2g) were then added to the solution and stirring was continued for 20 min. The resulting solution was stored in amber- coloured bottles. The composition of the nine batches of *in situ* gel formulations are presented in Table 1.

Evaluation of *in situ* gel formulations of metoprolol succinate

The *in-situ* gel formulations prepared were evaluated for the following parameters:

Physical appearance

All the formulations were observed visually for clarity and consistency.

pH determination

The pH of gel forming solution was measured using a pH meter (pH meter 720A, Thermo Electron Corporation, MA, USA) at 25±2°C.

Swelling Index

A sample of *in situ* gel of 10g was weighed accurately (W1) into a petri dish and 20mL of 0.1 N HCl was added. The petri dish was kept aside for 16 hours. The weight of swollen matrix gel (W_2) was measured and swelling index was calculated using following formulae:

$$W2/W1 \quad (5)$$

where, W_1 = initial weight of gel (10g) W_2 = weight of swollen matrix after 16 h.

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Percentage swelling was also determined from the percent change in weight of the *in-situ* gel after swelling in comparison to its initial weight.

Viscosity

The viscosity of each formulation was determined using the Brookfield rheometer (DV-11+ Pro model, Brookfield Engineering, USA) with spindle no.5 operated at 100rpm.

Determination of drug content

One millilitre of *in situ* gel solution (equivalent to 20 mg of metoprolol) was added to 100 mL of purified water to yield a solution of 0.2mg/mL. The UV absorbance of the sample was determined at a wavelength of 270 nm.

***In vitro* buoyancy**

The *in vitro* floating study was carried out by placing 1mL of gel inside a test tube containing 10mL of gastric fluid (0.1N HCl). The time taken for the formulation to emerge on the medium surface (floating lag time) and the time the formulation constantly floated on the surface of the medium (Total floating time) were noted.

***In vitro* drug release**

The release rate of drug from *in-situ* gel was determined using USP dissolution rate testing apparatus I (basket method) at 50 rpm. 900mL of 0.1N HCl was used as the dissolution medium, and temperature was maintained at 37±0.5° C. Samples (10mL) were withdrawn at the intervals of 5min for estimating the drug release using UV-Visible spectrophotometer at 270 nm using the Beer-Lambert equation obtained for the pure drug. Equal volume of fresh medium was used to replace the withdrawn samples.

Statistical Analysis

Statistical analysis was carried out using the two-way analysis of variance (ANOVA) on a computer software GraphPad Prism© 4 (Graphpad Software Inc. San Diego, CA, USA). At 95% confidence interval, probability, p values less than or equal to 0.05 were considered significant.

RESULTS AND DISCUSSION

Properties of Khaya gum

Yield

The yield of the Khaya gum from bark of *Khaya senegalensis* was 26.43% w/w. The yield was similar to those reported by Ozoude *et al,* 2020. The slight variation could be as a result of differences in environmental and soil conditions.

Morphology

Scanning electron micrographs of the Khaya gum presented in Fig 1 showed irregular shape with mean size of 220.55 ± 12.55 µm. The shape and surface characteristics of the particles were generally rough and granular.

Fourier Transform Infrared (FTIR) analysis

FTIR spectra of Khaya gum, sodium alginate and the blend of Khaya:alginate at ratio 2:1 are presented in Fig 2. The FTIR spectra of Khaya gum revealed some major bands and peaks. The peak at 3020.6 cm^{-1} could be attributed to C–H stretching vibrations in the substituted aromatic hydrocarbon. The peaks at 1371.7 cm^{-1} and 1471.1 cm^{-1} could be assigned to O–H bending of aromatic alcohol and carboxylic acids. The peak at 2348 cm^{-1} could be assigned to C=O stretching of ether, unsaturated ester while that of 3498.40 cm−1 could be assigned to O–H stretching of carboxylic acid. The plots of the blended polmers of Khaya:alginate, 2:1 showed how their peak integrity was maintained and suggests compatibility between the polymers.

Material and physicochemical properties

The material and physicochemical properties of Khaya gum are presented in Table 2. The pH of Khaya gum was 3.53, in the acidic range, showing its commercial and pharmaceutical importance. Acidic and neutral hydrocolloids are more widely used for pharmaceutical formulations because of better drug/excipient compatibility (Mahmud *et al*, 2008). Swelling index is a parameter used to determine the ability of gum to absorb fluid. Swelling may be as a result of divergent intensity of molecular association forces inside the particles (Sanni *et al*, 2005). The Khaya gum swelled to almost ten times of the original volume, revealing its high hydration capacity, an essential property in all hydrocolloid gels.

Particle density has been reported to affect the compaction behavior of powders (Okunlola and Odeku, 2009). The particle density for Khaya gum was 1.534±0.119 while the values of bulk and tapped

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densities were 0.681±0.013 and 0.845±0.021 respectively. The Carr's index and Hausner's ratio values are indicative of the flow properties of the gum and the compressibility. The values were calculated using the bulk and tapped densities. Carr's index of 16-20 indicates a good flow (Carr, 1965). Hausner's ratio of 1.19-1.25 indicates a fair flow. The Khaya gum had Carr's index of 19.31±3.507 and Hausner's ratio of 1.24±0.055, indicating good flow properties. The angle of repose of Khaya gum was 26.54±1.58 also confirming its good flow properties. The viscosity of the Khaya gum increased as the speed increased from 50 to 100 rpm with each spindle size used, indicating that the gum undergoes shear thickening. However, at constant speed, as the spindle size increased, the viscosity reduced.

Evaluation of *in situ* gel formulations of metoprolol succinate

Physical appearance

The *in-situ* gel formulations were clear and free of any particulate matter. Formulations containing Khaya gum (B1, B2, B3) had light-brown colour, more intense as the concentration of the Khaya gum increased. On the other hand, formulations containing HPMC (B4, B5, B6) and those containing Xanthan gum (B7, B8, B9) had clear coloration.

FTIR analysis

The FTIR spectra revealed that there were no significant changes in the peaks of drug spectrum, implying that the integrity of the drug was still maintained within the *in-situ* gel formulations and there was no incompatibility between the drug and gum polymers.

pH

The pH of the *in-situ* gel formulations were neutral to alkaline. This suggests non-irritancy and safety of the formulations when administered in the oral cavity. For the formulations containing Khaya gum and Xanthan, the pH decreased as the concentration of gum increased. On the other hand, for the formulations containing HPMC, the pH increased as the concentration of the gum increased (B6>B5>B4).

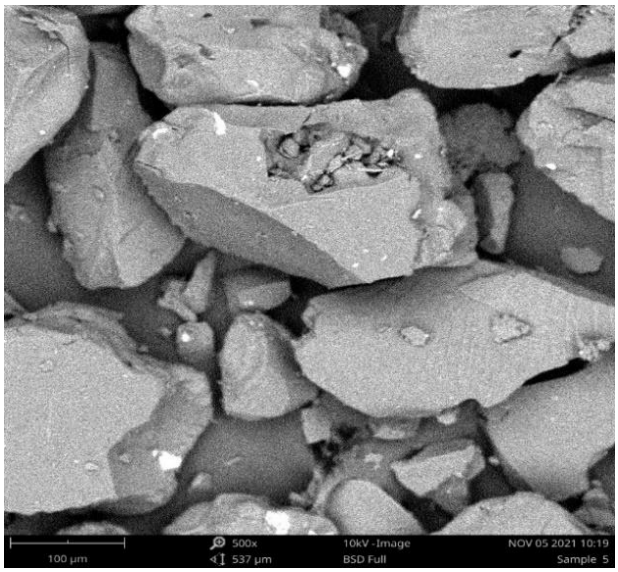

Fig. 1. *SEM image of Khaya gum mg x 500*

Table 2. *Material and physicochemical properties of Khaya gum (mean ± SD, n=3).*

Property	Value
Yield (%)	22.43±2.00
Particle size (µm)	220.55±12.10
Swelling index (%)	880.85±0.33
pH	3.53±0.02
Particle density (gcm-3)	1.534±0.119
Bulk density (g/mL)	0.681±0.013
Tapped density (g/mL)	0.845±0.021
Carr's Index	19.31±3.51
Hausner's ratio	1.24±0.03
Angle of repose °	26.54±1.58

Table 1. Batches of in situ gels formulations

Batch	Drug (g)	Khaya gum (g)	HPMC (g)	Xanthan gum (g)	Sodium alginate (g)	$CaCO_3$ (g)	Aspartame (g)	Sodium citrate (g)	Water to (mL)
B1	2.0	1.0	-	-	0.5	0.5	0.2	0.25	100
B2	2.0	1.5	-	-	0.5	0.5	0.2	0.25	100
B3	2.0	2.0		-	0.5	0.5	0.2	0.25	100
B4	2.0	-	1.0	-	0.5	0.5	0.2	0.25	100
B5	2.0	-	1.5	-	0.5	0.5	0.2	0.25	100
B6	2.0	-	2.0	-	0.5	0.5	0.2	0.25	100
B7	2.0	-	-	1.0	0.5	0.5	0.2	0.25	100
B8	2.0	-	-	1.5	0.5	0.5	0.2	0.25	100
B9	2.0	-	-	2.0	0.5	0.5	0.2	0.25	100

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Table 3. Properties of in situ gel formulations containing Khaya, Xanthan and HPMC gums

Formulation	pH	Swelling Index (w/w)	Swelling (%)	Drug content (%)	Floating lag time (s)	Total floating time (h)	t_{80} (min)
B1	7.71±0.15	2.387±0.116	138.70±9.10	99.60±6.15	60±9.10	>24	86.00±5.10
B2	7.39±0.16	2.499±0.152	139.85±10.22	99.60±8.20	95±10.22	>24	117.50±8.26
B3	7.17±0.01	2.518±0.096	151.78±7.85	103.70±7.22	106±10.75	>24	155.00±11.55
B4	7.98±0.17	2.239±0.167	123.88±11.15	99.00±5.10	90±7.07	>24	60.50±4.25
B5	8.05±0.18	2.294±0.100	129.43±8.15	105.00±6.10	105±8.19	>24	128.00±7.20
B6	8.26±0.17	2.396±0.156	139.56±11.60	96.00±4.20	119±5.60	>24	160.00±7.55
B7	7.78±0.04	2.298±0.187	122.79±9.50	97.00±6.16	45±2.15	>24	208.00±13.67
B8	7.48±0.15	2.393±0.190	139.32±7.40	98.10±8.56	87±5.10	>24	210.00±16.40
B9	7.60±0.12	2.493±0.090	149.34±10.03	104.20±7.20	95±4.80	>24	>240.00

Swelling

The swelling index and swelling percentage of the *in-situ* gel formulations was generally in the order of Khaya > Xanthan > HPMC, revealing that formulations containing Khaya gum showed highest swelling which was significant ($p < 0.0001$).

Viscosity

Generally, *in situ* gel formulations containing xanthan gum had the highest viscosity with the viscosity increasing with concentration of the Xanthan gum. However, formulations containing Khaya gum and HPMC had lower viscosity that decreased with concentration of the polymers.

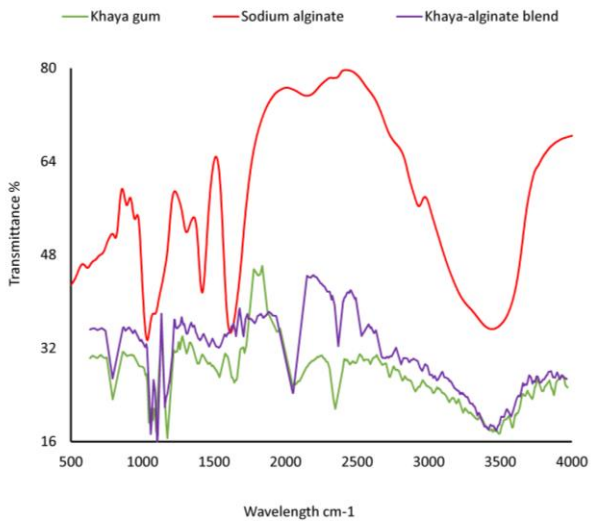

Fig. 2. *FTIR spectra of Khaya gum, sodium alginate and polymer blend of Khaa:alginate (2:1)*

Drug content

The percentage drug content for the *in-situ* gel formulations was in the range of 93.10±8.56 to 105.00±6.10 %w/w. All the formulations had uniform drug content with no significant difference ($p > 1.0$), revealing the efficacy of the method of preparation of the *in-situ* gel formulations.

***In vitro* buoyancy**

Generally, the floating lag time (FLT) was within the range of 45±2.15 to 119±5.60 s. The total floating time (TFL) for all the batches was >24 h. All the prepared formulas showed instant gelation upon contact with the stimulated gastric fluid. Good floating time of more than 24 hours was demonstrated by all the formulations. The ranking for FLT was Xanthan gum < Khaya gum < HPMC. This revealed that formulations containing Xanthan gum had the fastest FLT. The floating lag time decreased significantly ($p < 0.001$) with concentration of gum in each formulation.

The buoyancy of the formulations can be attributed to the presence of the floating agent, calcium carbonate. When the formulations came in contact with the acidic medium, gelation and cross-linking by Ca^{2+} ions occurred to provide a gel barrier at the surface of the formulation. Calcium carbonate demonstrated effervescence effect releasing carbon dioxide and calcium ions. The released carbon dioxide became entrapped in the gel network resulting in buoyant formulation. The calcium ions then reacted with alginate to produce a cross-linked three-dimensional gel network which restricted further diffusion of carbon dioxide and drug molecules thus resulting in extended period of floating and drug release, respectively (Panwar *et al*, 2012, Tenci *et al*, 2019).

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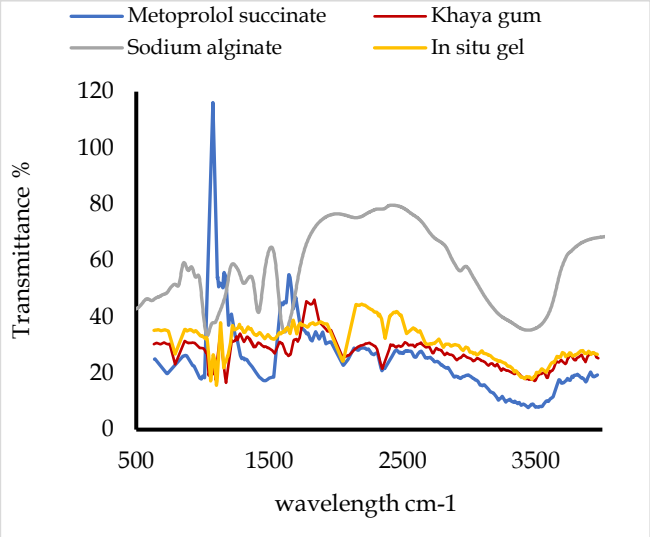

Fig. 3. FTIR spectra of metoprolol succinate, Khaya gum, sodium alginate and in situ gel formulation containing Khaya gum

***In vitro* drug release**

The amount of metoprolol succinate released in the dissolution medium was determined and the ranking for t_{80}, the time taken for 80% drug release, was generally in the order Xanthan > HPMC > Khaya revealing that formulations containing Xanthan gum showed the most sustained release while those containing Khaya gum gave the fastest release. It was however observed that initially at the lowest gum concentrations (1%w/v), those containing Khaya gum showed significantly more prolonged drug release ($p < 0.0001$) than those containing HPMC. The cumulative amount of drug released from the *in-situ* gels generally decreased with the concentration of the gums at a significant level ($p < 0.00001$). The decrease in the rate and extent of drug release with increase in polymer concentration could be attributed to increase in the viscosity of the polymer matrix as well as an increase in the diffusional path length which the drug molecules had to cross (Bashir *et al*, 2019).

In this study, effervescent floating *in situ* gel formulations were formulated using combinations of floatable and swellable polymers with sufficient gelling properties, in addition to the gas-generating agent, calcium carbonate, to liberate carbon dioxide gas upon contact with the gastric fluid. This enhanced the buoyancy of this system while the hydrophilic polymers controlled the drug-release rate. Once the hydrophilic polymer matrices contacted the aqueous media, a gel layer was formed in the gastric environment, which also created channels for further water penetration (Ai et al, 2019). Swelling ability is considered superior to floating duration, because once the delivery system swells to a size that is too large to pass through the pylorus and the swelling remains for a period of time, it results in prolonged gastric retention (Chen et al, 2015). Floating, on the other hand, is often affected by the amount of stomach fluid and food uptake. Natural, semisynthetic, and synthetic polymers have been used as drug delivery vehicles in floating delivery systems, each having their own specific characteristics and limitations. Khaya gum is a natural gum that is a hydrophilic carbohydrate polymer of high molecular weight. It readily absorbed fluid and swelled up to several times its original weight to give a viscous gel, an important characteristic that ensured buoyancy of the *in-situ* gel formulations and enhanced controlled drug release. Limitation of Khaya gum include the appearance of the formulations containing the gum which was a clear, light brown color in comparison to those of Xanthan gum and HPMC that were clearer even at the higher concentrations used in the *in situ* gel formulations. Other limitations of natural gum may include uncontrolled rate of hydration and reduced viscosity on storage. It was observed that HPMC K15M-based formulations had significantly lower swelling ($p< 0.05$) than Khaya gum but were able to control the release of the drug to a higher extent than those of Khaya-based formulations at higher concentrations. However, the sustained release observed for HPMC was not to the extent of those containing Xanthan gum. The higher viscosity of HPMC K15M matrix enabled it to form a rigid gel upon contact with aqueous media to control the delivery of the drug. Furthermore, higher amounts of HPMC showed slower erosion rate of the gelled layer when compared to Khaya gum.

Thus, it might be of value to employ this low cost, locally sourced and natural gum, Khaya, as a blend with HPMC in such gum-based *in situ* gel formulations to avoid complete dependency on the more expensive synthetic polymer. Areas for future research would consider polymer blending of Khaya gum with HPMC, at selected ratios, as an attractive approach to fabricate novel and unique floating *in situ* gel formulations with modified physical and chemical characteristics in which drug release can be controlled through changes in pH of the environment and physiochemical properties of the gum-blend. The control release pattern of formulations prepared using these combinations of Khaya gum and HPMC polymers would be expected to generate better results as it would follow various mechanisms of release.

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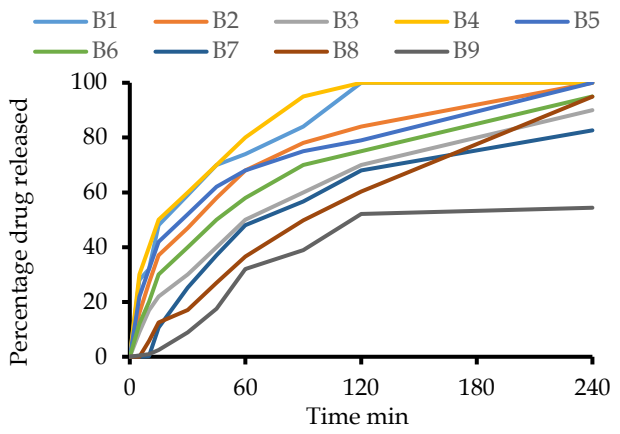

Fig. 4. Dissolution plots for the in situ gel formulations of metoprolol succinate

CONCLUSIONS

The extraction of Khaya gum from the bark of *Khaya senegalensis* (family Meliaceae) was successfully carried out with a yield of 26.43% w/w. Khaya gum showed high swelling and good flow properties. When used as a polymer in *in situ* gel formulations of metoprolol succinate, formulations containing Khaya gum gave higher swelling and a total floating time of >24 h, comparable with the *in situ* gel formulations containing HPMC and Xanthan gum as standards. Khaya gum gave the fastest drug release while Xanthan gum had the most prolonged release. Khaya gum showed potential as a polymer in *in situ* gel formulations of metoprolol for prolonged buoyancy and drug release.

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