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Original Article

# STUDIES ON *SIDA ACUTA* HYDROGEL I: PROCESSING AND PHYSICOCHEMICAL PROPERTIES OF THE DERIVED HYDROGEL OBTAINED FROM SOUTH EAST NIGERIA

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**ABSTRACT**

**Objective:** *Sida acuta* is a plant that is widely distributed in the subtropical regions where it is found in bushes, in farms and around habitations. This study was carried out to isolate hydrogel from this freely available natural source.

**Methods:** The sieved dried powder from the leaves of *Sida acuta* was macerated in distilled water. The mucilage formed was filtered and precipitated with equal volumes of isopropyl alcohol. This was repeated using ethanol and acetone respectively. The precipitated hydrogel was purified by washing twice with isopropyl alcohol, once with acetone and dried in the oven at 40 °C for 8h.

**Results:** The mean percentage yield of the hydrogel as obtained was 10.15±1.22, 9.24±0.74 and 7.90±0.03 %w/w for isopropyl alcohol, ethanol and acetone precipitated hydrogels respectively. The swelling index of the hydrogel in water was 10.00±0.02. The solubility of the hydrogel in water at 28 °C and 80 °C were 7.00±0.41 and 8.63±0.63 respectively. The solubility of the hydrogel in 0.1 N NaOH and 0.1 N HCl solutions were 11.86±1.75 and 5.67±0.58 mg/ml respectively. The loss on drying was 14 5±1.87% while total ash was 53.33±5.77 mg per 1 g hydrogel. The viscosity of a 1%w/v solution of the hydrogel using rotor 1 of a Brookfield viscometer at 30 rpm was 71.4±0.00 mPas. The pH of a 1%w/v solution was 6.60±009. The Carr's index and Hausner ratio were 38.77±1.69% and 1.63±0.05 respectively.

**Conclusion:** The hydrogel obtained from powdered dried leaves of *Sida acuta* may have potential in various drug delivery systems.

**Keywords:** *Sida acuta* hydrogel, Processing, Physicochemical properties, South East Nigeria.


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## INTRODUCTION

The quest for safer and more affordable pharmaceutical raw materials has made pharmaceutical scientists intensify research efforts towards developing raw materials of natural origin.

Natural gums and mucilages are preferred to the synthetic ones because they are biocompatible, cheap, and readily available. Also, the natural excipients are preferred to the synthetic and semisynthetic ones because of their apparent lack of toxicity, low cost, opening up jobs especially in developing countries and preserving foreign exchange [1–4]. Demand for these substances is increasing and new sources are being developed.

Gums and mucilages are typically heterogeneous polyuronides with a similar composition which upon hydrolysis yield sugars such as arabinose, galactose, glucose, mannose, xylose and various uronic acids [5]. Mucilages function as storage material, water storage reservoir and protection for germinating seeds. Mucilages are often found in epidermal leaf cells (*Senna*), seed coats (linseeds, *psyllium*), roots (*marshmallow*) and barks (*Slippery elm*) [6]. Gums are considered to be pathological products while mucilage is formed by normal metabolism. The gums are amorphous translucent substances which are insoluble in alcohol and most organic solvents. They are soluble in water and give a viscous, sticky solution while some form a jelly–like mass.

Gums are abnormal products, formed by injury on the plant, unfavorable conditions (e. g. drought) and by a breakdown of cell walls [7].

Gums and mucilages have diverse pharmaceutical applications such as a diluent, binder, a disintegrant in tablets, thickeners in oral liquids, protective colloids in suspensions, gelling agents in gels, and bases in suppository [8]. They are also used in cosmetics, paints, textiles, and paper making [9].

Some indigenous gums, such as *grewia* gum and *mucuna* gum have been studied locally in Nigeria as pharmaceutical excipients. *Grewia* polysaccharide gum is obtained by extraction from the inner stem bark of the edible plant *Grewia mollis*, *Linn*, (Fam. *Tiliaceae*). The gum has been isolated and some of its physicochemical properties have been evaluated [10]. The polysaccharide gum consists of glucose and rhamnose as the main monosaccharide components and galacturonic acid as the main sugar acid [10]. *Grewia* polysaccharide gum has found wide application in pharmaceutical formulations such as polymer matrices in sustained release solid dosage forms [11], binders in tablets [12] stabilizers or suspending agents in liquid dosage forms and in bioadhesive drug delivery systems [13]. *Mucuna* gum is a good suspending agent, a stabilizing agent in dosage formulations such as suspensions and emulsions [14], a good binder in tablets [15] and a good candidate for sustained drug delivery via microencapsulation [16].

The stability of the emulsion prepared with *mucuna* gum was compared with that of emulsions prepared with *acacia* or *tragacanth* and suspensions of sulphadimidine or zinc oxide prepared with *tragacanth* gum were compared with those prepared with *mucuna* gum. The result indicated that *mucuna* gum can be usefully employed as both an emulsifying and a suspending agent [14].

*Sida acuta* is a shrub belonging to *Malvaceae* family. The plant is widely distributed in the subtropical regions where it is found in bushes, in farms, and around habitations. *Sida* acuta is a plant of wide usage in traditional medicine. The picture of *Sida acuta* leaves is shown on fig. 1. Following these traditional usages, many studies have been conducted in laboratories for the efficiency of the plant. It is now evident that the plant has a good antiplasmodial activity due to its alkaloids, principally cryptolepine the main alkaloid of the plant. It is also demonstrated that the plant is active on several bacterial strains. Many other compounds which are demonstrated to have interesting pharmacological properties alone have been isolated from the plant, in addition, the plant may have many other properties since it has not been tested for all desired pharmacological activities [17].

Preliminary phytochemical screening of leaf extracts of *Sida acuta*. L shows that the chloroformic extract contains carbohydrates, alkaloids, saponins, fixed oil but no phytosterols while the ethanolic extract contains carbohydrates, alkaloids, saponins, fixed oil and phytosterols [18]. *Sida acuta* contained tannins, saponins, flavonoids and sterols chemical compounds [19].

**Fig. 1: *Sida acuta* leaves**

Searches through literature showed no citations on the isolation and uses of hydrogel obtained from *Sida acuta* in drug delivery and that stimulated the interest in this particular research work.

## MATERIALS AND METHODS

### Materials

Isopropyl alcohol, acetone (Guangxing Guanghua Chemical, China), absolute ethanol, chloroform (May and Baker, Dagenham England), Methanol (BDH, Poole, England) and other chemicals used were of analytical grades.

The leaves were collected from *Sida acuta* plants from bushes in the New G. R. A area of Trans–Ekulu, Enugu, Enugu state, Nigeria.

### Isolation and purification of hydrogel

The leaves from *Sida acuta* plant were dried, powdered, and passed through a sieve of aperture size 600 µm. A 200 g of the sieved dried leaves powder was mixed with 1500 ml of distilled water and allowed to macerate for 6 h. The mixture was boiled for 1 h at 100 °C to ensure complete break–up of cells to release the mucilage and kept aside for settling. After 2 h, the mixture was filtered, and to the filtrate (900 ml), equal volumes of isopropyl alcohol were added and kept in a refrigerator at 8–10 °C for 6 h. To the marc left, 1000 ml of distilled water was added and kept for about 1 h to wash out the remaining mucilage. The mucilage (1200 ml) was separated from the marc using a muslin cloth and precipitated with equal volumes of isopropyl alcohol [3]. The hydrogel was purified by using isopropyl alcohol and acetone as reported by previous researchers [20]. The hydrogel was soaked into two volumes excess of isopropyl alcohol. The hydrogel-solvent slurry was allowed to stand for 30 min. The precipitate was collected by filtration using a muslin cloth. washed twice with isopropyl alcohol and once with acetone [21]. Finally, it was dried in the oven at 40 °C for 8 h. The hydrogel was stored separately in a clean, dry, and closed container. This process was carried out in triplicate. The process was also repeated using absolute ethanol or acetone as the precipitating agent. The percentage yield for the hydrogels produced using the isopropyl alcohol, absolute ethanol and acetone respectively were recorded.

### Phytochemical analysis

The tests for identification of glycosides, sterols, flavonoids, saponins, tannins, phenols, terpenes and alkaloids were carried out on the powdered dried Sida acuta leaves and the precipitated hydrogel using the methods used by [22].

### Physicochemical properties

Organoleptic properties such as colour, taste, odour, shape and texture were determined for the *Sida* acuta hydrogel. Other physicochemical properties were determined. They include pH of 1% solution, swelling index, solubility, loss on drying, acute toxicity, the angle of repose, bulk and true densities, Hausner ratio, Compressibility index, ash values, microbial count and viscosity.

### pH

A 1%w/v solution of the *Sida acuta* hydrogel was prepared by dissolving 1 g of *Sida acuta* hydrogel in 100 ml of distilled water. Distilled water was used to calibrate a model HI 2211 pH/ORP meter (Hanna Instruments) after which it was used to determine the pH of the *Sida acuta* hydrogel. This was repeated four times. The pH for 1%w/v acacia solution was also determined.

### Bulk and tapped densities

The *Sida acuta* hydrogel was sieved through a 300 µm sieve. A 10 g *Sida acuta* hydrogel was weighed and poured into a 50 ml graduated cylinder and bulk volume recorded. The cylinder was tapped 100 times and the tapped volume recorded. The bulk and tapped densities were calculated. This was done three times.

### Carr's compressibility index

This was calculated from the bulk and tapped densities as follows:

$$Carr's\ Index = \frac{Tapped\ density \quad Bulk\ density}{Tapped\ density} X\ 100 \qquad \text{------1}$$

### Hausner ratio

This was also calculated from the bulk and tapped densities as follows:

$$Hausner\ Ratio = \frac{Tapped\ density}{Bulk\ density} \qquad \text{----------2}$$

### Angle of repose

This was determined by the Platform method. A hollow cylinder that was opened at both end, with a diameter of 5.5 cm was placed on top of a cream jar with diameter 5.5 cm on a table. A 20 g *Sida acuta* hydrogel was poured into the cylinder on top of the cream jar. The hollow cylinder was removed by pulling it up from the cream jar. The *Sida acuta* hydrogel formed a cone on top of the cream jar. The height and diameter of the cone were recorded. The drained angle of repose, θ was determined. This was done in triplicate.

$$\theta = \mathrm{Tan}^{-1}\frac{h}{r} \qquad \text{----------3}$$

Where h = height of cone and r = radius of the cone.

### Swelling index

The swelling index of the *Sida acuta* hydrogel was determined according to British Pharmacopoeia method 6 [23]. A 1 g of the *Sida acuta* hydrogel was transferred into a 50 ml ground glass stoppered measuring cylinder graduated over a height of 120 to 130 mm in 0.5 divisions. 25 ml of distilled water was added and shaken vigorously every 10 min for 1 h. It was kept for 24 h after which the volume of the swollen hydrogel was recorded. The swelling index is the volume in ml taken up by the swelling of 1 g of plant material under specified conditions. This was carried out in triplicate.

Swelling index was also determined using the method used by Sameer [24]. 1 g of Sida acuta hydrogel was weighed and transferred into a pre-weighed 15 ml centrifuge tube. 10 ml of distilled water was added to it and it was shaken thoroughly. This was centrifuged at 3500 rpm for 45 min. The centrifuge tube with the swollen hydrogel in it was weighed. This was done in triplicate and also for acacia hydrogel. The swelling index was calculated from the formula:

$$Swelling\ Index = \frac{Wf - Wi}{Wi} X\ 100\ \% \qquad \text{----------4}$$

Where Wf = final weight, and Wi = initial weight

### Effect of pH on the hydrogel swelling

The hydrogel was tested for its swelling characteristics at acidic and basic pH using 0.1N HCl, and 0.1N NaOH solution respectively,

**Viscosity**

The viscosities of different concentrations (1, 2, 3, 4, and 5 %w/v) of the *Sida acuta* hydrogel were tested at different rotor speeds (6, 12, 30 and 60 rpm) using rotor 3 of a Brookfield Viscometer (NDJ–5S Viscometer, England Lab science). The viscosity of a 1 % w/v *Sida acuta* hydrogel solution was determined at different temperatures (28, 40, 60 and 80 °C)

**Solubility**

The solubility of the hydrogel in water, ethanol, chloroform and acetone was determined. The solubility in water was determined according to the method described by Dakia *et al.* [25], with minor modifications. One g of the *Sida acuta* hydrogel was added to 100 ml distilled water and the mixture was stirred for 30 min. The solubility was measured by stirring the mixture at different temperatures, room temperature (28±2 °C) and elevated temperature (80 °C) in order to determine the effect of temperature on the solubility of the hydrogel. The hydrogel solution was then centrifuged at 3,500 g for 45 min to remove the insoluble material, and known volume (20 ml) of the supernatant was transferred into a crucible and oven dried at 105 °C for 24 h until constant weight [26]. The solubility was calculated by the weight difference and expressed in dry basis per volume of supernatant used. The solubility measurement was carried out in triplicate and the average of three individual measurements was considered for further data analysis.

**Determination of ash value [27]**

**Total ash**

A 2 g *Sida acuta* hydrogel was accurately weighed, in a previously ignited and tared crucible. It was spread in an even layer and ignited by gradually increasing the heat to 500-600 °C until it was white, indicating the absence of carbon. It was cooled in a desiccator and weighed. The total ash content was calculated in mg per g of *Sida acuta* hydrogel sample. This was carried out in triplicate.

**Acid-insoluble ash**

To the crucible containing the total ash, 25 ml of hydrochloric acid (~70 g/l) TS was added, covered with a watch-glass and boiled gently for 5 min. The watch-glass was rinsed with 5 ml of hot water and added to the crucible. The insoluble matter was collected on an ashless filter paper and washed with hot water until the filtrate was neutral. The filter paper containing the insoluble matter was transferred to the original crucible, dried on a hot-plate and ignited to constant weight. The residue was allowed to cool in a suitable desiccator for 30 min, then weighed without delay. The acid-insoluble ash content in mg per g of *Sida acuta* hydrogel sample was calculated. This was carried out in triplicate.

**Water-soluble ash**

25 ml of water was added to the crucible containing the total ash and boiled for 5 min. The insoluble matter was collected in an ashless filter paper. It was washed with hot water and ignited in a crucible for 15 min at a temperature not exceeding 450 °C. The weight of this residue in mg was subtracted from the weight of total ash. The content of water-soluble ash in mg per g hydrogel powder sample was calculated. This was carried out in triplicate.

**Loss on drying**

A 2 g *Sida acuta* hydrogel was weighed, put in a pre-weighed crucible and dried at 105 °C for 2 h in an oven. After 2 h, the new weight was recorded, and percentage weight loss on drying was calculated. Weight loss on drying was determined by formula,

$$Weight\ loss\ on\ drying = Initial\ weight\ of\ sample - final\ weight\ of\ sample \quad \text{--------5}$$

Percentage loss of moisture on drying was calculated using the formula.

$$LOD\ (\%) = \frac{Weight\ of\ water\ in\ sample}{weight\ of\ dry\ sample}\ X\ 100 \quad \text{----------6}$$

The weight loss on drying indicates the amount of moisture present in the material available to interact with other material.

**Determination of browning and charring temperatures**

The browning and charring temperatures of *Sida acuta* hydrogel were determined using a melting point apparatus (DBK Instruments, India).

**Microbial count [27]**

The microbial count of the *Sida acuta* hydrogel was performed for the total aerobic microbial count of bacteria and fungi using the plate count method. The limit of colony forming units (cfu) for bacteria was 300 and for fungi was 100.

**Plate count**

A 0.1 g of *Sida acuta* hydrogel was dissolved in sterilized water, and the volume was adjusted to 10 ml with the same medium. A Serial dilution was made by transferring 1 ml of hydrogel solution into a test tube and making it up to 10 ml with sterilized water. Further dilutions were made to obtain $10^{-4}$ and $10^{-5}$ hydrogel solutions. These processes were repeated using *acacia* gum.

For bacteria, nutrient agar was prepared at about 45 °C and poured into twelve Petri dishes of 10 cm diameter respectively and they were allowed to solidify. A 0.1 ml of the $10^{-4}$ *Sida acuta* hydrogel solution was transferred into three of the Petri dishes respectively. This was repeated using $10^{-5}$ *Sida acuta* hydrogel, $10^{-4}$ *acacia* gum, and $10^{-5}$ *acacia* gum solutions respectively. They were spread on the surface of the solidified medium in a Petri dish using a glass spreader. The hydrogel solutions were allowed to drain into the agar. The Petri dishes were inverted and incubated at 35 °C for 1 d. The number of colonies formed was counted and the results calculated using the average count for the respective three plates, up to a maximum of 300.

For fungi, Sabouraud glucose agar was prepared at about 45 °C and poured into twelve Petri dishes of 10 cm in diameter respectively and they were allowed to solidify. A 0.1 ml of the $10^{-4}$ hydrogel solution was transferred into three of the Petri dishes respectively. This was repeated using$10^{-5}$ *Sida acuta* hydrogel, $10^{-4}$ *acacia* gum, and $10^{-5}$ *acacia* gum solutions respectively. They were spread on the surface of the solidified medium in a petri dish using a glass spreader. The hydrogel solutions were allowed to drain into the agar. The Petri dishes were inverted and incubated at 28 °C for 3 d.

The number of colonies formed was counted and the results calculated using the dish with not more than 100 colonies.

**Acute toxicity studies**

The method specified by [28] was used with little modification. Ten male Winstar rats were procured from the animal house of Delta State University, Abraka. The animals were housed in cages and maintained under standard conditions at 28±2 °C and relative humidity 60-65 % and 12 h light and 12 h dark cycles each day for fourteen days. All animals were fed with the standard rodent pellet diet, and water *ad–libitum*. Permission was sought and received from the ethical committee on animal studies of Delta State University, Abraka. The animals were grouped into two, with each group having five rats. The rats were made to fast overnight and weighed the next day. An oral dose of 300 mg/kg body weight of *Sida acuta* hydrogel was administered to rats in group A while an oral dose of 2000 mg/kg body weight was administered to rats in group B. The rats were observed for 2 h for any sign of toxicity. They were further observed daily for 14 d for the sign of toxicity.

**RESULTS AND DISCUSSION**

**Isolation and purification of hydrogel**

The mean percentage yield (±SD) was 10.15±1.22, 9.24±0.74, and 7.90±0.03 % for *Sida acuta* hydrogel extracted with isopropyl alcohol, absolute ethanol, and acetone respectively.

**Organoleptic properties**

This is shown on table 1 below.

**Table 1: Organoleptic properties of *Sida acuta* hydrogel**

| Appearance | Colour | Odour | Taste | Texture |
|---|---|---|---|---|
| Powder | Light brown | Slight odour | Tasteless | Slightly rough |

**Table 2: Phytochemical tests of *Sida acuta* hydrogel**

| S. No. | Test | Dried powder from *sida acuta* leaves | *Sida acuta* hydrogel |
|---|---|---|---|
| 1 | Tannin | + | _ |
| 2 | Alkaloid | + | - |
| 3 | Saponin | + | - |
| 4 | Terpenoids | _ | _ |
| 5 | Steroid | + | + |
| 6 | Flavonoid | + | _ |
| 7 | Glycosides | + | + |
| 8 | Mucilage (Ruthenium red test) | + | + |

Key: += Present,-= Absent

**Phytochemical analysis**

This is shown on table 2.

**Physicochemical properties**

**pH**

The pH of a 1 % w/v solution of the hydrogel at 28±2 ° C was determined using a pH meter (HI 2211 pH/ORP meter, Hanna Instruments). The mean pH (.±SD) of 1 %w/v solution of *Sida acuta* hydrogel and *acacia* gum was 6.60±0.09 and 3.93±0.01 respectively This showed that both hydrogels were acidic, though *acacia* was more acidic. pH is one of the factors that affect the solubility of a solid in a liquid. The pH of the *Sida acuta* hydrogel suggested that it may be more soluble in a basic (e. g. simulated intestinal fluid, SIF) than acidic (simulated gastric fluid, SGF) medium.

**Bulk and tapped densities**

The mean bulk and tapped densities (±SD) were 0.24±0.01 g/ml and 0.39±0.10 g/ml respectively.

**Carr's compressibility index**

The mean compressibility index value (±SD) of 38.77±1.69 % indicated that the *Sida acuta* hydrogel had a very poor flow property. This showed that the cohesive forces between the particles were very high and this suggested that it could be used as a dry binder.

**Hausner ratio**

Mean value (±SD) of 1.63±0.05 indicated that *Sida acuta* hydrogel powder was cohesive and less free flowing. This showed that the interparticle friction was high.

**The angle of repose**

The mean drained angle of repose value (±SD) of 46.47±0.000 indicated a very poor flow. The hydrogel could not flow through the funnel which necessitated the use of platform method instead of funnel method. This may be due to the very small particle size of the hydrogel (<300 µm) which may favour the dominance of cohesive forces over repulsive forces.

**Table 3: Micromeritic properties of *Sida acuta* hydrogel**

| Property | Value |
|---|---|
| Angle of repose | 46.47±0.00 ° |
| Bulk density | 0.24±0.01 g/ml |
| Tapped density | 0.39±0.10 g/ml |
| Compressibility index | 38.77±1.69 % |
| Hausner ratio | 1.63±0.05 |

The number of experiments, n = 3, The data were given in mean±SD

**Swelling index**

The swelling index of 1 g of *Sida acuta* hydrogel in 25 ml of water was 10±0.2 ml. The swollen hydrogel occupied a mean volume (.±SD) of 10±0.2 ml while the remaining 15 ml (supernatant), containing the dissolved hydrogel which was viscous but mobile. The swelling index determined using the method of sameer *et al.* [24] was 984±31 %. This showed that the *Sida acuta* hydrogel could be used as a swellable hydrophilic matrix in the formulation of sustained release preparations. The 1 g *acacia* gum did not swell but dissolved in water in both methods to form a slightly viscous *acacia* mucilage.

**Effect of pH on mucilage swelling**

The swelling index of 1 g of the *Sida acuta* hydrogel was 8±0.01 ml and 25±0.02 ml, in 25 ml of 0.1 N HCl and 0.1 N NaOH respectively. In the dilute acid medium, the hydrogel became swollen (8 ml) and floated on top, while it dissolved and formed a thick viscous mucilage in dilute alkaline solution. The *acacia* gum did not swell but dissolved completely to form *acacia* mucilage in the 0.1 N HCl and 0.1 N NaOH solutions respectively.

**Viscosity**

As the concentration of the *Sida* acuta hydrogel solution increased from 1 to 5 % w/v as shown on table 4 and fig. 2 below, using rotor (spindle) 3 of a Brookfield viscometer, at a speed of 6 rpm, the viscosity increased from 0 to 12,520±0 mPas, at room temperature (28±2 °C). Table 4 and fig. 3 also show that for a given concentration of the hydrogel solution (e. g. 5 % w/v), the viscosity decreased (12,520±0 to 1960±0 mPas) as the speed of rotation of the rotor or shear rate increased (6 to 60 rpm). Table 5 shows the effect of temperature on the viscosity of Sida acuta hydrogel. The viscosity of a 1%w/v solution of *Sida acuta* hydrogel at room temperature (28±2 °C) using spindle (rotor) 1 at 30 rpm is 71.4±0.00 mPas. This is comparable to *grewia* gum which has a viscosity of 2.685 mPas at 0.5% w/v concentration and is used as a binder and as a suspending agent [10]. The viscosity of *Sida acuta* hydrogel decreases (71.4±0.00 to 25.2±0.00 mPas) as the temperature increases, (28 to 80 °C), as shown in fig. 4. The rheological properties suggest that the hydrogel may be used as a binder in solid dosage forms and as viscosity enhancer or suspending agent in liquid dosage forms.

**Table 4: The viscosity of different concentrations of Sida acuta hydrogel using rotor 3 at room temperature (30 °C) and at different speeds (rpm)**

| Speed | Concentration of sida acuta hydrogel | | | | |
|---|---|---|---|---|---|
| | 1% w/v | 2% w/v | 3%w/v | 4% w/v | 5% w/v |
| 6 rpm | - | 120±0 mPas | 920±0 mPas | 4620±0 mPas | 12520±0 mPas |
| 12 rpm | - | 120±0 mPas | 740±0 mPas | 3400±0mPas | 9290±0 mPas |
| 30 rpm | - | 96±0 mPas | 592±0 mPas | 2220±0 mPas | 3944±0 mPas |
| 60 rpm | - | 88±0 mPas | 522±0 mPas | 1734±0 mPas | 1960±0 mPas |

The number of experiments, n = 3, The data were given in mean±SD.

**Table 5: Viscosity of 1% w/v sida acuta hydrogel solution at different temperatures**

| Temperature ( °C) | Viscosity (mPa. s) |
|---|---|
| 28 (Room temperature) | 71.4±0.00 |
| 40 | 46.4±0.00 |
| 60 | 33.8±0.00 |
| 80 | 25.2±0.00 |

The number of experiments, n = 3, The data was given in mean±SD

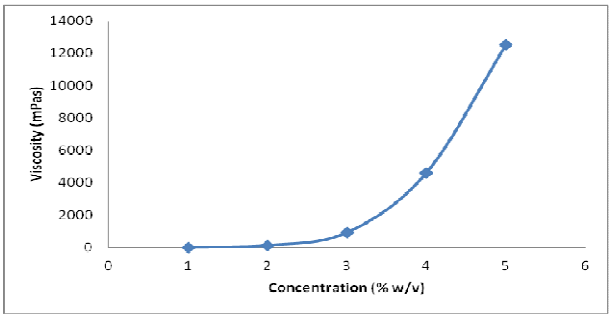


**Fig. 2: Viscosity vs concentration at room temperature (30 °C) using rotor 3 at 6 rpm, The number of experiments, n = 3, The data were given in mean±SD**

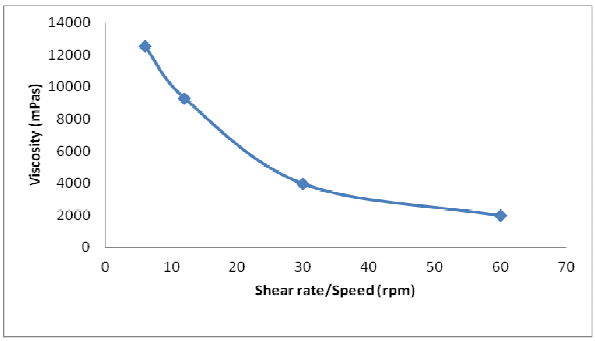


**Fig. 3: Rheogram of 5% w/v sida acuta hydrogel solution at room temperature using rotor 3, The number of experiments, n = 3, The data were given in mean±SD**

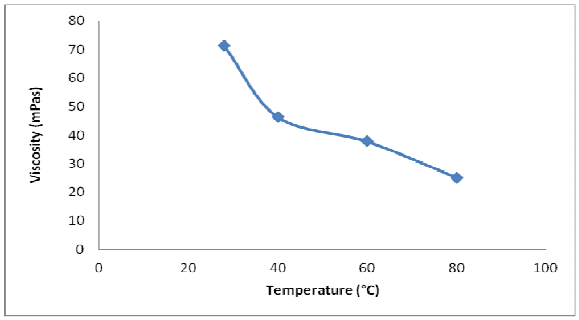


**Fig. 4: Viscosity vs temperature using rotor 1 at 30 rpm, The number of experiments, n = 3, The data were given in mean±SD**

**Solubility**

The solubility of a substance is the amount of the substance that passes into solution in order to establish the equilibrium at constant temperature and pressure, to produce a saturated solution. Some factors such as temperature and pH affect the solubility of solids in liquids. [29] The mean solubility (±SD) of 1 %w/v *Sida acuta* hydrogel in distilled water at room temperature (28±2 °C) and 80 °C were found to be 7±0.41 mg/ml and 8.63±0.63 mg/ml respectively, while the solubility in 0.1 N HCl and 0.1 N NaOH solutions were 5.67±0.58 mg/ml and 11.86±1.75 mg/ml respectively. The official limit for solubility of *acacia* gum in distilled water at room temperature is 500 mg/ml or Ig of *acacia* dissolves in 2 ml of distilled water to form a slightly viscous solution. The results show that *Sida acuta* hydrogel is poorly soluble in distilled water at room temperature when compared to *acacia* gum. Also, the solubility increased as the temperature increased. The solubility decreased in 0.1 N HCl but increased in 0.1 N NaOH solutions. This was in agreement with the pH value of the hydrogel (6.60±0.09) which was slightly acidic. Basic substances are soluble in acidic solvents, vice versa. An increase in solubility of a new drug in an acidic solution compared with its aqueous solubility suggests a weak base, and an increase in alkali, a weak acid [30]. The fast swelling of the hydrogel in water may be one of the reasons for its poor solubility. Particles at the outer surface absorb water and swell which prevents water from reaching those in the interior easily. This feature may be useful if the hydrogel is used in the formulation of swellable hydrophilic matrix tablets.

**Ash values**

The total ash method is designed to measure the total amount of material remaining after ignition. This includes both "physiological ash", which is derived from the plant tissue itself, and "non-physiological" ash, which is the residue of the extraneous matter (e. g. sand and soil) adhering to the plant surface. Acid-insoluble ash measures the amount of silica present, especially as sand and siliceous earth. The mean total ash value (±SD) for *Sida acuta* hydrogel was 53.33±5.77 mg per 1 g hydrogel (5.33%w/w), while the mean acid insoluble ash (±SD) and mean water soluble ash (±SD) were 10±0.02 mg per 1 g hydrogel (1.0%w/w) and 10±0.05 mg per 1 g hydrogel (1.%w/w) respectively. The British Pharmacopeia limit of total ash and acid insoluble ash for *acacia* is not more than 4.0% and not more than 0.5% respectively [31]. The value obtained showed that there was a low level of impurity from extraneous and plant matters. The values obtained indicated that most of the impurities present as total ash were acid soluble i. e few sand and siliceous earth. The value obtained for water-soluble ash was also small (1%w/w). These values were comparable, though slightly higher than that obtained for *acacia* gum.

**Loss on drying**

British Pharmacopoeia's limit for percentage loss on drying for *acacia* gum is, not more than 15 %. The result obtained for mean

percentage loss on drying (±SD) was 14.5±1.87 %, and 14.5±1.32 % for *Sida acuta* hydrogel and *acacia* gum respectively. The loss on drying obtained for the *Sida acuta* hydrogel was comparable to that of *acacia*. The value obtained for *acacia* was within the official limit. The result showed that *Sida acuta* hydrogel absorbed water easily without dissolving in it. This showed that the hydrogel could be used as a hydrophilic swellable matrix. The presence of such quantity of moisture showed that the hydrogel may be liable to microbial attack, therefore it should be properly stored in a dry closed container.

**Determination of browning and charring temperatures**

The hydrogel started browning at 265 °C and charred at 268 °C.

**Microbial count**

There was no growth in the saboraund glucose agar plates containing the different dilutions of *acacia* gum and *Sida acuta* hydrogel solutions. This showed the absence of fungi in the *acacia* gum and *Sida acuta* hydrogel. The nutrient agar plates that contained $10^{-4}$ and $10^{-5}$ dilutions of *Sida acuta* hydrogel contained 132 cfu (1.32 X $10^7$ cfu/ml) and 79.5 cfu (7.95 cfu x $10^7$ cfu/ml) of bacteria respectively. This was comparable to that obtained from the nutrient agar plates that contained 10-4 and 10-5 dilutions of *acacia* gum which contained 100 cfu (1.00 X $10^7$/ml) and 78.5 cfu (7.85 X $10^7$ cfu/ml) of bacteria respectively. Therefore, when *Sida acuta* hydrogel is used in the formulation of liquid dosage forms as a suspending agent, preservatives should be added.

**Acute toxicity studies**

At the expiration of the 14 d as shown on table 5, there was no sign of toxicity or death recorded in the rats. From the study, the LD 50 value of *Sida acuta* hydrogel was above 2000 mg/Kg, because neither obvious signs of toxicity nor death were observed.

**Table 5: Acute toxicity studies of sida acuta hydrogel**

| Group | Body mark | Body weight (g) | Dose (mg) | Number of death |
|---|---|---|---|---|
| 1 | HR | 100 | 30 | 0 |
| 1 | HRT | 90 | 27 | 0 |
| 1 | HRR | 90 | 27 | 0 |
| 1 | HT | 110 | 33 | 0 |
| 1 | HTT | 100 | 30 | 0 |
| 2 | 2HH | 100 | 200 | 0 |
| 2 | 2IT | 80 | 160 | 0 |
| 2 | 2II | 90 | 180 | 0 |
| 2 | 2TT | 100 | 200 | 0 |
| 2 | 2HT | 90 | 180 | 0 |

Sample size: 10 rats

## CONCLUSION

*Sida acuta* hydrogel was isolated from powdered dried leaves of *Sida acuta*. The hydrogel obtained had physicochemical properties that indicated that it could be used as pharmaceutical excipients such as a binder, suspending agent and swellable hydrophilic matrix. It could also be used for investigation in nanoformulation of some drugs in novel drug delivery alone or in combination with other biopolymers.

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## CONFLICT OF INTERESTS

Declared none

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