Original Article

**In-Vitro Anti-Sickling Activity of Selected Medicinal Plant to Explore Herbal Remedies for Sickle Cell Anemia**

Shilpa Vaishnava*, V D Rangari
SLT Institute of Pharmaceutical Sciences, Guru Ghasidas Vishwavidyalaya, Bilaspur Chhattisgarh-495001, India.

**ARTICLE INFO**

**Objective:** To explore medicinal plants available in Chhattisgarh for its anti-sickling activity by using various in-vitro test and find a suitable herbal remedy for dreadful disease i.e sickle cell anemia.

**Methods:** Medicinal plants were extracted with suitable process and the dry extracts obtained were subjected to in-vitro antisickling activity by Emmel's test, Hemoglobin S solubility test/Hemoglobin polymerization, and osmotic fragility/Erythrocyte membrane stability activity.

**Results:** The result of the activity indicated that the medicinal plants extracts Wrightia tinctoria and Carica Papaya have shown prominent activity while Mangifera indica and Holarrhena antidysenterica depicted moderate activity for sickle cell disease.

**Conclusion:** Present Study conclude that for treating dreadful disease like sickle cell anemia herbal remedies can be one of the best approach, this study provides suitable herbal leads by providing its anti-sickling activity using various scientific models. Among various herbal extract results has indicated that the extract of *Wrightia tinctoria* (WTE) shows significant activity.

**Keywords.** Sickle cell, polymerization, deoxygenation, herbal plant.

---

1. **INTRODUCTION**

Each year, over 300,000 neonates born with sickle cell disease (SCD) and half of them die before the age of 5 years. This disease is more pronounced in developing countries . The prevalence of sickle cell carriers found to be more among different tribal groups which varies from 1 to 40 % in India . Majority of these tribal groups live in rural areas and not able to afford expensive proposed therapies such as the medullar implantation and repeated blood transfusion which increases our interest to investigate a novel and safe medicine for SCD. SCD is inherited chronic disease in...
which red blood cells (RBC) become crescent-shaped instead of disc-shaped. It is caused by mutation in the sequence of beta globin in 6th position, replacement of a polar amino acid (glutamic acid) by a less polar one (valine) leads to polymerization of hemoglobin S (sickle hemoglobin) in the red blood cells 3. This aggregation modifies the shape of blood cells and makes them fragile and less flexible; that causes many complications in sicklers like hemolytic anemia, painful vaso-occlusive events, vascular remodeling, acute and chronic organ injury, and shortened lifespan 4.

Pathophysiological studies have shown that the dense, polymerized and dehydrated red cells may play a central role in acute and chronic clinical manifestations of SCD. During the deoxygenation which follows passage of RBCs in the microcirculation, the Hb molecule undergoes a conformational change 5. In HbS, replacement of the hydrophilic group in the beta-globin chain by the hydrophobic residue makes that this last one establishes hydrophobic interactions with other hydrophobic residues on the beta-globin chain of another deoxy-HbS molecule 6. Here due to lack of oxygen, deoxy HbS protein polymerize, leading to a rigid chain and induce the characteristic SS-RBC shape (sickle shape). This process needs a certain time to be primed, the so-called “delay time”, which is inversely proportional to the intracellular concentration of HbS. One of the distinguishing characteristics of SCD is the presence of dense erythrocytes, formed as a result of cell dehydration and loss of potassium (K+) 7. Normal RBCs cells keeps intercellular Na+ and Ca** ions low and K+ and Mg** ions high and the pathways are modulated by cellular energy. Due to ATP depletion, Ca** concentration increase 3-4 time in SCD patients 8. Cells contain few or no endocytic vesicles for storage of large amount of Ca++, it activate Ca**-dependent K* channel (Gardos channel), loss of K* with accompanying movements of Cl- and water thereby resulting dehydration and hemochrome formation. It follows that loss of RBCs deformability and cell to cell adherence 9. Several studies on pathophysiology of sickle cell indicate that anti-sickling agent may act on inhibition of polymerization or inhibit RBCs cell hemolysis.

Very few ethno medicinal remedies for the treatment of SCD have been reported in the literature due to secrecy attached to the treatments of this disease. Our present study was performed with the aim of screening the medicinal plants used to treat SCD in tribal area of Chhattisgarh state of India. The anti-sickling activity of the plants extracts were evaluated in-vitro on Sickle cell patient’s blood using Emmel’s test, polymerization inhibition assay and osmotic fragility test 10.

2. MATERIAL AND METHOD

Survey and Collection of Plant Material

The medicinal plant surveys conducted in the Achanakmar-Amarkantak region of Chhattisgarh state of India with the help of traditional healers known as Baigas and Vaida, and this survey provided us leads such as Wrightia tinctoria R.Br (Apocynaceae) (leaves), Carica papaya (Caricaceae) (unripe fruits), Butea monosperma (Lam.) kuntze (Fabaceae) (fresh flowers), Bombax ceiba (Asclepiadaceae) (fresh flowers), Mangifera indica (Anacardiaceae) (leaves) and Holarrhena antidysenterica Wall (Apocynaceae), (seeds). These plants were collected from Chhattisgarh Medicinal Plant Board and the University Campus of Guru Ghasidas University Bilaspur. Plants were authenticated in Guru Ghasidas Central University, Bilaspur & voucher specimen were deposited at herbarium of Department of Botany (No. Bot/GGV/2018/25), in Guru Ghasidas Central University Bilaspur.

Extraction

W. tinctoria R.Br (leaf) (WTE), M. indica (leaf) (MIE) and H. antidysenterica (leaf) (HAE) were subjected to soxhlet extraction. 500 gm of the dried crude drug was taken and extracted for 72 hours using ethanol as a solvent. C. papaya (unripe fruit) (CPE), B. monosperma (fresh flower) (BME), B. ceiba (fresh flower) (BCE) were extracted by using maceration method. Fresh flower were collected and petals were separated from flower, crushed and placed in methanol for overnight in a refrigerator. After filtration, filtrates were concentrated and dried using rotary evaporator.

Biological samples

The blood samples used in the present study were provided by SRL Laboratories Bilaspur, theses sample were collected by the laboratory taken from adolescent patients known to have sickle cell disease in the Chhattisgarh area. None of the patients had been transfused recently with Hb AA blood. All anti-sickling experiments were carried out using a sodium citrate suspension of freshly collected blood. In order to confirm their SS nature, the above-mentioned blood samples were first characterized by hemoglobin electrophoresis on cellulose acetate gel at pH 8.5. They were confirmed to contain SS red blood cells and were stored at ± 4°C in a refrigerator.

a) The Emmel’s test

Blood samples were kept in contact with plants extracts at different concentrations [with the physiologic solution (NaCl 0.9%, an isotonic solution of the cellular medium used to allow the osmotic regulation and hence to avoid precocious hemolysis of red blood cells) as the dilution solvent] according to Emmel’s test procedure 11. In this study, Emmel’s test was performed as mentioned in Mpiana et al, 2007. A drop of physiological solution kept on a glass slide followed by addition of blood sample (one drop), glass slide were covered and kept for incubation for 24 hours in anaerobic conditions, which leads deoxygenation and transform them into sickle shaped. Glass slide were observed under microscope. The numbers of observed erythrocytes were determined using neubauer’s cell.
b) Hemoglobin S solubility test / hemoglobin polymerization

HbSS polymerization was assessed by the turbidity of the polymerizing mixture at 700 nm using 2% Sodium metabisulphite as reductant or deoxygenating agent [12]. 4.4 ml of 2% solution of sodium metabisulphite (Na2S2O3), 0.5 ml normal saline and 0.1 ml of plant extract were pipetted into a cuvette, shaken and the absorbance was noted at 700 nm every five minutes for 30 minutes. This represented the control. Distilled water was used as blank in all assays. In the main assay, 4.4 ml of 2% solution of sodium metabisulphite, 0.5 ml of extract and 0.1 ml of hemoglobin solution (HbSS) were pipetted into a cuvette and the optical density reading taken as above. The rates of hemoglobin polymerization were calculated from the formula of average change in optical density / absorbance against time in minutes [13]. The rate of polymerization inhibition (% PI) versus time was calculated using the following formula:

\[
% PI = \frac{Absorbance \ of \ untreated \ HbSS - Absorbance \ of \ treated \ HbSS}{Absorbance \ of \ untreated \ HbSS} \times 100
\]

Before zero time (period of pre- incubation), the HbS which was soluble in aqueous medium was converted into deoxy-Hb form for which solubility is much reduced after chemical treatment by the sodium metabisulphite 2% (hypoxi) thus initiating a beginning of polymerization. At time zero, the absorbance of untreated HbS increases (due to the formation of polymer to tactoid which absorbs at 700 nm) where the absorbance of treated Hb decreases at the same wave length (inhibition of polymerization).

3. RESULT

The results obtained from the above tests i.e. Emmel’s test, Hemoglobin S solubility test and Erythrocyte membrane stability activity has been presented as follows.

Effect of extract on sickle cell RBCs morphology (Emmel’s test)

Figure 1.1 show the shape change in RBCs normal blood sample, negative controlled (untreated) and positive control (treated with C. papaya extract) and plant extract treated sample. Calculate average value of radius, perimeter and surface area of RBCs with different plant extracts is shown in Table 1. This table indicates that where RBCs with the plant extract shows change of sickle shape to round shape. This statement confirmed by changes in radius shape and both surface area and perimeter of treated cells [13]. The results confirm that tasted plants have antisickling activity (p < 0.05). The results are presented in Table 1 and Fig. 1-8.

Table 1: Average values of radius, perimeter and surface of erythrocytes before and after treatment with plant extracts

| S. no. | Sample and code name | Surface (μη2) | Perimeter (μη) | Radius (μη) |
|--------|----------------------|--------------|---------------|-------------|
| 1      | Negative control (NC)| 19.2 ±1.0    | 51.7±1.5      |             |
| 2      | C. papaya extract (CPE)| 51.8±3.22     | 18.4±2.3     | 3.1±0.35    |
| 3      | W. tinctoria extract (WTE)| 33.7±1.7      | 19.39±1.1     | 3.3±0.3     |
| 4      | H. antidysenterica extract (HAE)| 29.2±3.26     | 20.23±2.19    | 3.17±0.43   |
| 5      | M. indica extract (MIE)| 21.1±2.14     | 32.9±3.14     |             |
| 6      | B. monosperma extract (BME)| 20.6±1.23     | 33.0±1.3      |             |
| 7      | B. ceiba extract (BCE)| 20.2±6.2      | 31.9±1.42     |             |

Fig 1: Normal blood cells

Fig 2: Negative control sickled cells
Effect of extract on Polymerization of RBCs

The effect of extract on the polymerization of deoxy-HbS can be determined by studying the solubility of deoxy-HbS in the absence and in the presence at 250mg/ml concentration of plant extracts. This was done by monitoring the polymerized HbS at 700 nm at different time interval. Graph shows the changes in polymerization with time interval. Negative control, positive control and different plant extract shown in graph 1.

Effect of extracts on osmotic fragility test:

The effect of different plant extracts on the membrane stability of RBC can be evaluated by comparing the percentage of hemolysis of untreated and treated SS RBCs using the osmotic fragility test. Graph 2 shows the percentage lysis of untreated and treated SS RBC at different saline concentrations.
4. DISCUSSION

Fig. 1 shows normal condition of RBCs untreated sodium metabisulfite hypoxia condition. All RBCs are disc shaped and healthy in appearance. Fig. 2 is from negative control treated sodium metabisulfite but not treated with any drug. Fig. 3 positive control treated with sodium Meta bisulfite then C. papaya extract used as a standard here and can see significant changes in RBCs as compare to negative control. Fig. 4 (WTE) and 5 (HAE) shows the majority of the erythrocytes recovered in normal shape like positive control. Fig 6 (MIE) shows less recovery of RBCs and fig 7 (BME) and 8 (BCE) are not that much recovery. So we cannot consider sample BME & BCE effective in sickle cell. As it can be seen, a normalization of sickle cell treated with WTE, HAE & MIE. It was reported that unripe Carica papaya extract used for normalizing the sickle cell erythrocytes 16. Here the WTE result is almost similar to CPE. From the above result it can be assured that the activity of W. tinctoria extract (WTE) is almost similar with C. papaya extract.

Above results are statically treated according to Tukey’s multiple range test 17. That enables the determination of a significant difference between the untreated and treated group. Shape normalization can be quantitatively evaluated from the values of parameters such as (1) the surface area (in mathematical analysis surface area of round cells is higher than sickle shape and study literature 18 says that higher surface area increase the capability of carrying oxygen), (2) the perimeters ( when round shape change in sickle shape it shrink from middle and elongated from corner thus the value of perimeter is higher in sickle than round) and (3) the radius ( radius only possible to count when cell is round shape not apply for sickle shape) . Based on above theory it can be observed from the results given in table-1 that the perimeters of untreated RBCs are higher than those of the treated groups with WTE and HAE. Surface area and radius of cells are higher in treated group compare to untreated group. Because of the sickle shape not change in the samples treated with MIE, BCE, BME and untreated RBCs, software not give those groups RBCs radius result. Based on all three parameter result shows that antisickling activity of WTE is higher than to CPE (positive control). However HAE show positive activity near to CPE. Remaining extract does not show effect on sickle cells. The above results are in agreement with our findings on shape of RBCs that revalued that biconcave shape higher the surface area higher oxygen caring capacity 19. These result agreement for bioactive plants and confirm the antisickling activity of WTE and HAE.

Pathophysiology of SCD has been suggested to change in sickle hemoglobin polymerization. Literature 20 says polymerization of deoxy HbS reduce its oxygen affinity and cause sickling. We can predict that higher the percent of polymerization inhibition (PI), higher is oxygen affinity. Higher the oxygen affinity we compare the result of different extract it shows maximum difference between negative control and positive control groups. WTE extract has shown better activity than standard positive control. HAE & MIE showed moderate % PI activity as compared to earlier one. Someplace BCE and BME showed less than 50% of PI. In this paper we discus about the delay time. This delay time is sensitive to Hb polymerization. In SCD therapy longer delay time,decrease the polymerization and decrease the probability of RBCs sickling 21. In graph we can see delay time is between 0 to 5 min. that maximum changes need in polymerization is between this times then the graph will continue with small changes. Longer delay time reduce the polymerization 22. Therefore it can be assumed that, anti-sickling activity seems to be achieved by the direct interfering in delay time.

Sickle erythrocytes have been reported to have a distorted volume-to-surface ratio when compared to normal erythrocytes and so a shift to the left in the osmotic fragliogram suggests a higher osmotic resistance for most sickle cells. This shift was observed in the study, showing that the extracts were able to protect the integrity of the erythrocyte membrane by, increasing its resistance to osmotic stress/lysis, and thus reducing membrane fragility. From these erythrocyte studies, it can be reported that aqueous extract of C. papaya reduced hemolysis and confirm some protective effect on erythrocyte membrane. This shift was observed in the study, showing that the extract was able to protect the integrity of the erythrocyte membrane, increase its resistance to osmotic stress/lysis, and thus reduce membrane fragility. In graph 2 indicate higher percent of lysis is higher in CPE, WTE and HAE as compared to negative control. That indicates that higher the osmotic fragility means higher the rounded cells of RBCs 23.

5. CONCLUSION

Results of this study has indicated that the ethanol extract of Wrightia tinctoria (WTE) shows significant or better antisickling activity as compare to the standard Carica papaya extract (CPE). MIE and HAE showed moderate activity. BCE and BME failed to show antisickling activity in these in- vitro studies. The ability of the extracts, in this study, to normalize the SS blood erythrocytes, polymerization inhibition and osmotic fragility may represent a rational explanation for the use of these plants W. tinctoria seeds or C. papaya in treating SCD. These species have not yet been reported to exhibit antisickling effects. Further studies are, therefore, necessary to evaluate the potential of these plants as effective antisickling agents.

6. ACKNOWLEDGEMENT

Thanks to AICTE, New Delhi for the funding of the research project entitled “Phytochemical investigation, anti-sickling activity studies and formulation development of some Indian medicinal plants for the treatment and management of sickle cell anemia”. Shilpa Vaishnava is thankful to Guru Ghasidas Central University for Non-NET-UGC Fellowship. Authors
also acknowledge the support of SRL Laboratories, Bilaspur, for antisickling activity on blood of sickle cell anemia patients.

7. REFERENCES
1. Gentilini M., “Me´decine tropical”, Flammarion, Paris, 1986.
2. Singh KS. People of India: An introduction. Calcutta, India: Anthropological Survey of India, 1992.
3. Girot R, Begue’ P, Galacte’ros F, “La dre´panocyrose”, Hors collection, Paris, 2003, 320-22.
4. O. S. Platt, D. J. Brambilla, W. F.Rosse et al., Mortality in sickle cell disease—life expectancy and risk factors for early death” The New Eng J Medi 1994; 330 (23):1639–1644.
5. Edelstein SJ, Telford JN, Crépeau R H. Structure of fibers of 13. Sickle cell hemoglobin. Proc Natl Acad Sci 1973; 70: 1104-7.
6. Murayama M. “Structure of sickle cell hemoglobin and molecular mechanism of the sickling phenomenon, Clin. Chem., 1967; 14: 578-88.
7. Odievre M H, Verger E, Pinto A C S. and Elion J, Pathophysiological insights in sickle cell disease. Indian J Med Res 2011; 134: 532-537.
8. Kato GJ, Gladwin MT, Steinberg MH. Deconstructing sickle cell disease: reappraisal of the role of hemolysis in the development of clinical sub phenotypes. Blood Rev 2007; 21: 37-47.
9. Mapiana P T, Ngbolu K N, Mugodo V, Tshibangu D.S.T., Atibu E.K.,Tshilanda D.D. and Misengabu N.M., Anti sickle erythrocytes haemolysis properties and inhibitory effect of anthocyanin extracts of Tremat orientalis on the aggregation of human deoxyhemoglobin s in vitro. J Med Sci 2011; 1(3): 129-137.
10. Courtejoie J, Hartaing I. Laboratoire et Sante, Saint Paul, Kinshasa, 1992.
11. Mapiana P T., Tshibangu D S T., Shetonde O.M.and Ngbolu K.N., “In vitro antidrepanocytary activity (anti-sickle cell anemia) of some Congolese plants” Phytomedicine, 2007; 14: 192–195.
12. Iwu M.N., Igboke A.O., Onwubiko H., Ndu U.E., Effect of cajanus cajan on gelation and oxygen affinity of sickle cell hemoglobin. J Ethnopharmacol 1988; 22:90-104.
13. Nwaoguikpe, Nwazue R., “The phytochemical, proximate and amino acid compositions of the extracts of two varieties of tiger nut (cypereus esculentus) and their effects on sickle cell hemoglobin polymerization” J. of Medi. & Medical Sci., 2010; 1(11): 543-549.
14. Nanfack P., Cabral B.N.P., and, Anatole P.C., “The in vitro antisickling and antioxidant effects of aqueous extracts Zanthoxylum heitizii on sickle cell disorder”, BMC Comp. and Alt. Medi. 2013; 13:162.
15. Mapiana P T, Mugodo V. and Tshibangu D. S. T., Antisickling activity of anthocyanin from Bombax pentadrum, Ficus capensis and Ziziphus mucronata: Photo degradation effect. J Ethnopharma. 2008; 120: 413–418.
16. Oduola T, Idowu T O, Bello I. S., “Hematological response to intake of unripe Carica papaya fruit extract and the isolation and characterization of caricapinoside: a new antisickling agent from the extract. Asian J Pharma. & Clin. Res 2012; 5: 3-9.
17. Mapiana P T, Ngbolu N K T., Bokota M.T., Kasonga T.K., Atibu E.K., Tshibangu D.S.T., and Mudogo V. In vitro effect of anthocynin extract from justice secunda Vahl on the solubility of hemoglobin S and membrane stability of sickle erythrocytes. Blood Transfus 2010; 8: 248-54.
18. Mapiana P T., Mugodo V. and Ngbolu N K T. In vitro antisickling activity of anthocynin from Ocimum basilicum L. (Lamiaceae), Int. J Pharmacol., 2007a; 3: 371-74.
19. Mapiana P T, Mugodo V., Tshibangu D.S.T., and Ngbolu N. K.T., “In vitro antisickling activity of anthocynin extracts of Congolese plant: Alchornea cordifolia, M. Arg.J.Med. Sci., 2007b; 7: 1182-86.
20. Adesanya S.A., Idowu T.B. and Elujoba A. A., antisickling activity of Adansonia digitata’ Plant med, 1988; 54:374-78.
21. Chikezie P. C., “Sodium metabisulphite induced polymerization of sickle cell hemoglobin incubated in the extracts of three medicinal plants (Anacardium occidentale, Psidium guajava and Terminalia catappa)” Afr.J.Biotechnol, 2011; 10: 6154-61.
22. Jaja S I, Kehinde M O, Gbenebitse S., Mojiminyi F. B. O., and Ogunbemi A. I., “Effect of vitamin C on arterial blood pressure, irreversible sickled cells and osmotic fragility in sickle cell anemia subjects,” Nigerian J of Physio. Sci., 2000; 16(1):14–18.
23. Elekwa I, Monanu M O, Anosike E.O., “Effects of aqueous extracts of Zanthoxylum Macrophyllya roots on membrane stability of human erythrocyte of different genotype. Biochem., 2005; 17: 7-12.

Conflict of Interest: None
Source of Funding: Nil