Chapter 02

REVIEW OF LITERATURE
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2.1. General Introduction

The management of sickle cell disease (SCD) is widely sought through the use of plant extracts, which provides relief during the “crises stage” of disease. It is evident that sickled erythrocytes can be reversed by use of appropriate combinations of different plant extracts. However, no single plant has been reported to serve the purpose alone.

Researchers have concentrated on two broad areas in this regard. One line of research focuses on the identification of phytochemicals which possess antisickling properties, by studying the \textit{in vitro} reversal of erythrocytes by using various concentrations of the chemical against the previously sickled erythrocytes. Likewise, sickling inhibitory properties of various chemicals are studied, in which erythrocytes pretreated with different concentrations of the chemical are tested for sickling activity. The reversal studies were largely conducted \textit{in vitro} using blood samples from sickling patients and subjecting them to oxygen stress using sodium metabisulphite to obtain sickle cells and then treating with various concentrations of plant extracts and then counting the cells to study the reversal of the sickling process. On the contrary, inhibition studies concentrated on treating with various concentrations of plant extracts prior to subjecting the samples to oxygen stress. This was then compared with untreated controls and the inhibition potential was determined using standard statistical methods. Both the methods were highly successful in determining the antisickling activity of the plant concerned.

The antisickling effects shown by plants are solely due to their underlying phytochemicals in the form of active principles. Studies on phytochemical analysis of plants are abundant, both from India and abroad, however; reports ascertaining antisickling propensities are few. In this section review of available literature dealing with a) phytochemical analysis of plants and b) antisickling activities of plant extracts are being dealt separately.
2.2. Phytochemical Analysis of Plant Extracts

Karwni et al. (2004) studied the phytochemicals present in Momordica balsamina leaf extracts. They found alkaloid in high concentrations followed by saponins, tannins and reducing compound, respectively. Sterols and triterperes were absent, while tannins, alkaloids, saponins were present. Johannes et al. (2004) studied phytochemicals in different species of *Erythroxylum* and reported the presence of alkaloids, quinines, saponins and cardiac glycosides in low amounts, while the lipids/essential oils and carotenoids were absent. Amines were only identified in *E. havanense* and flavonoids were detected in high levels in two, *E. areolatum* and *E. confusum*.

Jimoh and Oladiji (2005) studied the phytochemicals from in the seeds of *Piliostigma thonningii*. They reported crude protein, carbohydrate, mineral elements, saponins, flavonoids, phenols, glycosides, anthraquinones and cardiac glycosides while tannins, steroids, phylobatannins and triterpenes were found to be absent.

Oloyede (2005) reported the presence of saponins and cardenolides, potassium, sodium, calcium, iron, phosphorus, zinc, copper, magnesium and manganese in considerable quantities in mature unripe pulp of *Carica papaya* fruits. Proximate analysis of the pulp showed the presence of starch, sugars, crude protein, crude fat, moisture and fiber in various proportions. Tavares et al., (2005) reported the presence of stepholidine in genus Fusaea.

Edeoga et al., (2005) reported the phytochemical constituents of some Nigerian medicinal plants. Alkaloids, tannins, flavonoids and cardiac glycosides were present in all the plants studied while tannins and cardiac glycosides were absent in *Stachytarpheta cayennensis* and *Tridax procumbens*, respectively. Only *Scopania dulcus, Euphorbia heterophylla, Pysalis angulata* and *Emilia coccinea* showed the presence of terpenoids. Okwu and Josiah (2006) evaluated the chemical composition of two Nigerian medicinal

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plants, *Aspilia africana* and *Bryophyllum pinnatum*. The results revealed the presence of bioactive constituents comprising alkaloids, saponins, flavonoids, phenols and tannins. These medicinal plants contained ascorbic acid, riboflavin, thiamine, and niacin. These herbs are good sources of minerals such as Ca, P, K, Mg, Na, Fe and Zn.

Idu *et al.* (2006) studied the phytochemistry and antimicrobial effects of water, methanol, chloroform and petroleum ether extracts of *Senna alata* leaves. Extracts tested at a final concentration of 500 µg mL produced *in vitro* antimicrobial activities in assays against clinical isolates of *Staphylococcus aureus*, *Candida albicans*, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonans aeruginosa* and *Bacillus subtilis*. Phytochemical analysis of the plant extracts showed the presence of phenols, tannins, anthraquinoes, saponins and flavonoids.

Aliyu *et al.* (2008) studied comparatively the phytochemicals present in some Nigerian medicinal plants. They found alkaloids and flavonoids in *Stachytarpheta angustifolia*, saponins and phenols in *Anisopus manni* whereas; *Anchomanes difformis* contained lower amounts of alkaloids, saponins and total phenolics.

Mike (2008) analysed the phytochemicals present in plants of the genus *Acalypha* (Euphorbiaceae). They showed the presence of alkaloids, tannins, saponins and cardenolides in the five species of *Acalypha*. Ayoola *et al.* (2008) showed the presence of flavonoids, terpenoids, saponins, tannins and reducing sugars in some select plants of Nigeria. Furthermore, they reported absence of cardiac glycosides and alkaloids in *M. indica*; absence of alkaloids and anthraquinones in *P. guajava* and absence of anthraquinones in *Vernonia amygdalina*.

Musa *et al.* (2008) reported the presence of alkaloids, flavonoids, saponins, steroids/terpenoids, stilbenoids and tannins in the methanolic leaf extract of *Cissus cornifolia*.  

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Himal et al. (2008) studied the phytochemicals present in some medicinal plants of Nepal. They reported the presence of alkaloids, glycosides, terpenoids, steroids, flavonoids, tannins and reducing sugars in *Azadiracta indica*, *Colquhounia coccinea*, *Curcuma longa*, *Elsholtzia fructicosa*, *Eucalyptus globules*, *Ocimum santrum*, *Rhodendron setosum* and *Zanthoxylum aromatu*.

Stephen et al. (2009) studied the bark of *Khaya grandifoliola* and reported the presence of alkaloids, tannins, saponins and flavonoids. Iniaghe et al. (2009) assessed the proximate composition and phytochemical constituents of the leaves of *Acalypha hispida*, *Acalypha marginata* and *Acalypha racemosa*. Proximate analysis revealed moisture, crude fat, ash, crude protein, crude fibre, and carbohydrates. *Acalypha marginata* contained moisture, crude fat, ash, crude protein, crude fibre and carbohydrates; while *Acalypha racemosa* contained moisture, crude fat, ash, crude protein, crude fibre and carbohydrates. The phytochemicals detected in both aqueous and methanolic extracts of each of the different species of leaves were the same and are phenolics, flavonoids, hydroxyl-anthraquinones and saponins. Steroids and phlobatannins were detected in *Acalypha hispida* and *Acalypha racemosa*, while glycoside was detected only in *Acalypha hispida*.

Malu et al. (2009) reported the phytochemical constituents of the seeds of *Tetracarpidium conophorum* as alkaloids, tannins, saponins, flavonoids and glycosides. Gurinder Kaur and Daljit Arora (2009) performed phytochemical analysis of the seeds of three plants, *Anethum graveolens*, *Foeniculum vulgare* and *Trachyspermum ammi* and reported the presence of alkaloids, tannins, saponins, flavonoids and cardiac glycosides.

Doss (2009) reported the phytochemical composition of some Indian medicinal plants, *Asteracantha longifolia*, *Psassiflora edulis*, *Berberis tinctoria*, *Sphaeranthus indicus* and *Solanum trilobatum*. All the plants were found to contain Phenols, Cardiac glycosides, Steroids, Saponins and Tannin except for
the absence of flavonoids and terpenoids in *A. longifolia* and alkaloids in, *P. edulis, A. longifolia, B. tinctoria* and *S. indicus* respectively.

Akharaiyi and Boboye (2009) reported saponins and alkaloids in the leaves bark and roots of *Senna hirsute, Landolphia dulcis* and *Daniella oliveri*. Sreelatha and Padma (2009) reported the presence of phenolics, flavonoids and trace amounts of alkaloids, in both mature and tender leaves of *Moringa oleifera*.

Omale and Emmanuel (2010) evaluated and reported the presence of alkaloids, cyanide, tannins, flavonoids and saponins in *Euphorbia heterophylla* leaf extract.

Ekeanyanwu *et al.* (2010) reported the presence of alkaloids, cyanogenic glycosides, resins, tannins, sterols and saponins in the raw tuber of Nigerian Tigernut (*Cyprus esculentus* L), however only alkaloids, sterols and resins were observed in the roasted tuber. Antinutrient composition yielded oxalates, phytate, saponins, tannins and cyanogenic glycosides.

Duru and Onyedineke (2010) reported the presence of some bioactive compounds; alkaloids, anthranoids, anthraquinone, glycosides, saponins, starch and tannins following the phytochemical analysis of ethanolic extracts of the mesocarp of *Voacanga africana*.


Imaga *et al.* (2010) studied the phytochemical and antioxidant nutrient constituents of *Carica papaya* and *Parquetina nigrescens* extracts. Phytochemical screening confirmed the presence of folic acid, vitamin B12, alkaloids, saponins, glycosides, tannins and anthraquinones. This study also showed that each of
these plants extracts contained flavonoids and the antioxidant vitamins A and C. Cyanogenic glycosides were absent from both plant extracts, indicative of the non-toxic effects of these plants when taken orally.

Eghareva et al. (2010) performed phytochemical and proximate analysis of the leaves of *Piliostigma thonningii* and reported the presence of bioactive constituents of carbohydrates, glycosides, flavonoids, tannins, saponins, balsams, volatile oil, and terpenes; however, phlobatannins, resins, alkaloids, anthraquinones and sterols were not detected.

Karthishwaran et al. (2010) conducted phytochemical investigation of methanolic extract of the leaves of *Pergularia daemia* by TLC, HPLC and HPTLC. The scan of the methanolic extract of *P. daemia* evidenced the presence of multiple components in the extract. The results obtained after qualitative analysis confirmed by spectral analysis. It shows the presence of two major peaks observed in the HPTLC, HPLC and IR spectrum and exhibited the presence of two principle components in the methanolic extract of the leaves.

Nisha Shri et al. (2010) conducted phytochemical screening of the root and rhizome of *Corallocarpus epigaeus* by way of phytochemical extraction, phytochemical testing and thin layer chromatography (TLC) and reported the presence of alkaloids and flavonoids.

Dike (2010) assessed the proximate, phytochemical and nutrient compositions of fruits, seeds and leaves of some Nigerian plant species. Fat was highly represented in the family of Annonaceae. Calcium, manganese, potassium, sodium, phosphorous, iron, zinc and lead were at low concentration. The leaves had higher percent protein, carbohydrate, moisture content and higher concentration of saponin than those of the fruits.

Gangwa et al. (2010) reported the presence of triterpenoids, flavonoids and sterols from *Lagenaria siceraria* fruits. Kiran Kumar et al. (2010) studied
and reported the presence of alkaloids, flavanoids, phenols, glycosides, tannins, saponins and lignins in the leaf extract of *Mirabilis jalapa*. Maurya and Singh (2010) studied the total phenolic contents in *Adhatoda vasica* leaves. Patel *et al.* (2010) showed the presence of alkaloids, tannins, saponins, amino acids, flavonoids, steroids, glycosides and carbohydrates in the seeds of *Celosia argentea*.

Siddique *et al.* (2010) studied the antioxidant activity and quantitative estimation of phenols and flavonoids in different parts of *Aegle marmelos*.

Mohammad *et al.* (2011) reviewed the phytochemicals from some medicinal plants of Bangladesh. They extensively investigated over 48 medicinal plants and several microbial strains that have resulted in the isolation and characterization of 133 compounds, including 33 new molecules. Terpenoids, alkaloids, flavonoids and glycosides were the major classes of constituents. The crude extractives and several purified molecules demonstrated statistically significant inhibition of growth of microorganisms. Furthermore, extensive chromatographic separation and purification of the extracts obtained from 48 medicinal plants of Bangladesh afforded a total of 133 pure chemical entities, including 33 new molecules. The structures of these compounds were elucidated by spectroscopic studies and chemical derivatization. Some of the isolated compounds exhibited significant antibacterial and antifungal activities, when subjected to antimicrobial screening by disc diffusion technique.

Proximate and phytochemical analysis of *Hymenocardia ulmoides* and *Vitex ferruginea* leaves, used as medicinal plants in Congo-Brazzaville, were done by Andzouana and Mombokuli (2011). The proximate analysis revealed presence of moisture, proteins, fat, fatty acid, carbohydrate and ash content of the leaves of both of the plants. The phytochemical screening of the leaf extracts revealed the presence of alkaloids, flavonoids, glycosides, saponins, steroids, tannins and triterpenoids in ethanol-water extracts of both plant samples. In
methanol-chloroform extracts of *H. ulmoides* leaves, glycosides and saponins were not detected, while flavonoids, saponins and tannins were not found in *V. ferruginea*. Anthraquinones were absent in all the extracts of both plants.

Okoh-Esene *et al.* (2011) performed proximate and phytochemical analysis of leaf, stem and root of *Eugenia uniflora* (Surinam or Pitanga cherry). The leaves were found to contain saponin, saponin glycosides, flavonoids, tannins and phenol. Anthracenes, balsams, alkaloids and volatile oils were absent. The stem contained phenol, tannin and flavonoid while the root contained just saponin. Proximate analysis revealed moisture, ash, fat, crude fibre, nitrogen and carbohydrates in varied proportions for leaves, stem and roots of *Eugenia uniflora*.

Ayoola *et al.* (2011) performed phytochemical and nutrient evaluation of *Tetracarpidium conophorum* (Nigerian walnut) roots.

Phytochemical screening was performed by Zaheer *et al.* (2011) on various extracts of flowers and bark of *Spathodea campanulata*. Tests showed the presence of carbohydrates, alkaloids, tannins, glycosides in extracts of flowers and presence of steroids, carbohydrates proteins, tannins glycosides and alkaloids in bark of the plant.

Yadav and Agarwala (2011) studied the phytochemicals of some medicinal plants (*Bryophyllum pinnatum, Ipomea aquatica, Oldenlandia corymbosa, Ricinus communis, Terminalia bellerica, Tinospora cordifolia*, and *Xanthium strumarium*). Proteins, carbohydrates, phenols, tannins, flavonoids, saponins, were detected in all of the plant parts tested viz., *B. pinnatum* (Leaves), *I. aquatica* (Leaves), *O. corymbosa* (Whole plant), *R. communis* (Roots), *T. bellerica* (Leaves), *T. cordifolia* (Leaves), *T. cordifolia* (Stem), and *X. strumarium* (Leaves).
A qualitative and quantitative phytochemical analysis was performed by Subramanian and Suja (2011) for the detection of alkaloids, phenols, flavonoids, tannins in dry rhizome of *Alpinia purpurata*.

Khan *et al.* (2011) conducted phytochemical screening of some Pakistani medicinal plants, viz., *Mentha spicata*, *Withania coagulaus*, *Perilla frutescums*, *Oenothcra bienris*, *Canna bisstative*, *Tribulus terrists*, *Acorus calamus*, *Adhatoda vasica*, *Achyanthus asper*, *Medicago sativan*, *Myrtus commanis*, *Chenopodium*, *Convolvulus arrenisis*, *Erigeron steroids*, *Tegetis erecta*, *Solanumus nigrum*, *Echinacea purpurea*, *Withania sommifera*, *Paillea fruticosa* and *Mentha longifolia*. Anthraquinones, Terpenoids, Flavonoids, Saponins, tannins, alkaloids and cardiac glycosides were present, except the reducing sugars. In plants like, *P. frutescums*, *C. stative*, *A. avasica*, *M. commanis*, *Erigeron steroids*, *P. fruticosa* and *M. longifolia*, the tannins were absent, however the rest of the phytochemicals were present in all the selected plants.

Karimi *et al.* (2011) studied the phytochemicals in methanolic extracts of leaf, stem and root from different varieties of *Labisa pumil*. Leaves of *var. pumila* exhibited significantly higher total saponin content than *var. alata* and *lanceolata*. HPLC analyses of phenolics and flavonoids in all three varieties revealed the presence of gallic acid, caffeic acid, rutin, and myricetin in all plant parts. Higher levels of flavonoids (rutin, quercitin, kaempferol) were observed in *var. pumila* compared with *alata* and *lanceolata*, whereas higher accumulation of phenolics (gallic acid, pyrogallol) was recorded in *var. alata*, followed by *pumila* and *lanceolata*.

Adejumo *et al.* (2011) studied the phytochemical and antisickling activities of *Entandrophragma utile*, *Chenopodium ambrosiodes* and *Petiveria alliacea*. The study revealed the presence of saponins, tannins and alkaloids. The use of these plants by the traditional medical practitioners in the treatment of SCD is justified.
Amir Mohammad et al. (2011) studied the phytochemical composition of selected medicinal plants viz., *Woodfordia fruticosa*, *Adhatoda vasica*, *Chenopodium ambrosoides*, *Viburnum cassinifolium*, *Euphorbia hirta*, *Vitex negundo*, *Peganum harmala*, *Broussonetia papyrifera*, *Taraxacum officinale*, *Urtica dioica*, *Verbascum thapsus*, *Caryopteris grata* and *Mimosa rubicaulis*. In the 13 Plants studied, alkaloids, saponins, tannins, anthraquinones, flavonoids, flavonols and chalcones, terpenoids, phlobatanins, coumarins, steroids and cardiac glycosides were analyzed qualitatively whereas alkaloids, flavonoids, tannins, phenols and saponins were analysed quantitatively too. In *W. fruticosa* and *V. cassinifolium*, all the constituents were detected except coumarins and steroids. All the constituents were detected in *A. vasica*, *C. ambrosoides* and *P. harmala* except anthraquinones, coumarins, steroids and terpenoids. *V. negundo* exhibited all the studied phytochemicals except coumarins, steroids and phlobatanins.

Mohanty et al. (2011) studied the phytochemicals present in whole plant extracts of *Cajanus cajan* Linn. They reported maximum presence of carbohydrates in ethyl acetate extract, whereas, petroleum ether and ethanolic extracts showed low presence of these compounds. Water extract showed zero availability of carbohydrates. Proteins and amino acids were present considerably in ethyl acetate and ethanolic extracts while petroleum ether and water extracts showed little presence.

Moses (2012) performed phytochemical analysis and TLC of eight selected medicinal herbs (*Carissa spinarum*, *Urtica dioica*, *Warburgia ugandensis*, *Senna didymobotrya*, *Physalis Peruviana*, *Biden spilosa*, *Leonotis ne petifolia* and *Toddalia asiatica*) used for the treatment of diabetes, malaria and pneumonia in Kisii, Kenya.

Andzouana and Mombouli (2012) assessed the phytochemical constituents of the Leaves of a Wild Vegetable- *Ochthocharis dicellandroides* (Gilg). Results
revealed presence of moisture, crude protein, carbohydrate, crude fat, energy, and ash. While the elemental analysis revealed that the minerals detected in the leaves were calcium, phosphorus, potassium, magnesium and iron in decreasing order of concentrations. Aluminum and sodium were found as trace elements and manganese was not detected. The phytochemicals detected in the leaves were alkaloids, flavonoids, steroids, triterpenoids and glycosides, while anthraquinones tannins and saponins were not detected. The results showed high concentrations of flavonoids and steroids and a moderate amount of glycosides.

Uzama et al. (2012) studied the phytochemicals, proximate and elemental analyses of *Securinega virosa* leaf extracts. Phytochemical screening of the leaves indicated the presence of alkaloids, tannins, carbohydrates, balsams, saponins, phenols, flavonoids and cardenolide. The study revealed the leaves of *Securine gavirosa* to be a potential source of nutrition, minerals and useful drugs for human body.

Arya *et al*. (2012) performed phytochemical analysis and showed the presence of flavonoids, tannins triterpenoids, saponins, sterols, alkaloids and carbohydrates in the leaf extracts of *Psidium guajava* L.

Wani *et al*. (2012) studied comparative phytochemical analysis of the extracts of *Podophyllum hexandrum* and *Rheum emodi*. They reported that flavonoids and terpenes are present strongly in both the plant extracts. Glycosides were absent in both the extracts, but the saponins were present in extracts of *Podophyllum hexandrum*, it was however, absent in extracts of *Rheum emodi*. Proteins were high in the extracts of *Podophyllum hexandrum* compared to extracts of *Rheum emodi*.

Syed Imran *et al*. (2012) performed phytochemical analysis of *Leonotisne petifolia*, a wild medicinal plant of the family Lamiaceae, and reported the
presence of bioactive constituents comprising alkaloids, flavonoids, phenolics, tannins, glycosides, steroids and saponins in different solvents.

Peter et al. (2012) analysed the bioactive components in the leaf extract of *Stylosanthes fruticosa* and reported 33 bioactive phytochemical compounds, mostly phenolic compounds and flavonoids derivatives, carbohydrate and glycosides, saponins and phytosterols compounds, proteins and alkaloids. These different active phytochemicals have been found to possess a wide range of activities, which may help in the protection against incurable diseases.

Adedeji et al. (2012) performed phytochemical screening of two tropical moss plants: *Thidium gratum* and *Barbula indica* grown in Southwestern Ecological Zone of Nigeria. The aqueous extracts of *Thidium gratum* and *Barbula indica* were tested using standard procedures, to identify the phytochemical constituents. The extracts were screened for the presence and quantities of alkaloids, flavonoids, phenols, saponins and steroids with a view to assess their therapeutic values in ethno-medicine. The results of the phytochemical screening revealed the presence of alkaloids, flavonoids, phenols, saponins and steroids in varying quantities in the two moss plants but there was absence of phenol in *Barbula indica*. These results established these two plants as potential source of useful drugs in treatment of ailments.

Amar et al. (2012) performed phytochemical analysis of five Algerian plants (*Euphorbia guyoniana, Parentucellia viscosa, Verbascum signatum, Ecbalium elaterium* and *Scabiosa atropurpura*) and reported the presence of many chemical classes such as: flavonoids, sterols or triterpenes, saponins, tannins, carotenoids and alkaloids. In addition the evaluation of the antibacterial activity of two extracts of the endemic *Euphorbia guyoniana* by the disc diffusion assay was performed against six bacteria strains.

Bibi et al. (2012) phytochemically evaluated *Aster thomsonii Jagessar* and Allen (2012) analysed *Terminalia catappa* for natural products and reported
selective presence of sterols, triterpenes, carotenoids, flavones aglycone, emodols, coumarins, tannins, reducing compounds, anthraquinones, steroid glycosides, alkaloids, cardenolides, saponins, flavanosides, cholesterol, flavanoids, amino acids, phlobatinins, cholesterol and cardiac glycosides in the various solvent type extracts.

Okoro et al. (2012) reported the presence of tannins, saponins and sterols in the stem bark of the plant. Alkaloids, glycosides and flavonoids were not detected in the plant.

Ogunjinmi et al. (2012) done the phytochemical screening of crude extracts of *Moringa oleifera* seeds and reported that alkaloids, glycoside, flavonoids and saponins were present in both the hexane and methanolic extract of *Moringa oleifera* seeds. Majority of the extracts contained the secondary metabolite such as alkaloids, glycosides, flavonoids, tannins, saponins, steroids and reducing sugars.

Tariq (2013) conducted for the phytochemical analysis of *Terminilia chebula* plant extracts of leaves, fruits, seed, stem and roots. They reported the presence of flavonoids, alkaloids and terpenoids. The phenol content was highest in roots followed by seeds, leaves, stem and fruits. The sugar content was highest in leaves followed by fruits, stem, root and seed. The protein content was highest in fruits followed by seed, leaves, stem and roots.

Wadood et al. (2013) performed the phytochemical analysis of some medicinal plants (*Acacia nilotica, Psidium guajava, Luffa cylindrical, Morusalba, Morusnigra, Momordica charantia, Fagonia cretica, Punica granatum, Ficus palmate* and *Prunuspersica*) reported the presence of terpenoids, phlobatannins, reducing sugars, flavonoids and alkaloids.

Asowata et al. (2013) reported the presence of saponins, tannins, steroids, flavonoids, terpenoids, cardiac glycosides and reducing sugars were detected in
the aqueous extract of _N. vogelli_. Phlobatannins and alkaloids were absent from the analysed aqueous and alcoholic leaf extracts of _Napoleonaea vogelli_. Saponin and terpenoid were found to be present in the analysed _N. vogelli_ leaves.

Okechukwu _et al._ (2013) analysed the ethanolic extract of _Moringa oleifera_ leaf and showed the presence of tannins, carbohydrates, saponins, glycosides, reducing sugars, terpenoids, steroids, flavonoids and alkaloids. However, phytochemicals such as resins, proteins and fat oils were not detected.

Dewole _et al._ (2013) studied comparatively the two plants, _Cola nitida_ and _Cola acuminata_; results showed that _Cola acuminata_ had more alkaloids, tannins and saponin than _Cola nitido_. The phenol and flavonoid contents of the two kola nuts were almost equal.

Aarti _et al._ (2013) studied _Murraya koenigii_ (curry) and _Camellia sinensis_ (tea) leaves and showed the presence of tannins, saponins, sugar and quinones; Jahan _et al._ (2013) showed the presence of reducing sugar, tannins, steroids and alkaloid types of secondary metabolites in the ethanolic leaf extract of _Trema cannabina_; Uduak and Akpan (2013) studied _Aspilia africana_ and _Tithonia diversifolia_ stems and reported the presence of flavonoids, tannins, saponins and cardiac glycosides.

Mohamed and Paul (2013) studied the _Hypha enethebaica_ L. Fruits and identified 17 compounds and quantified including 2 cinnamic acid derivatives, 5 flavonoids, 6 fatty acids, 2 sphingolipids, a lignan, and a stilbene. Sugar composition in the fruit was characterized and quantified by 1H-NMR (nuclear magnetic resonance) and fruit organic extracts anti-inflammatory potential was assessed _in vitro_ by cyclooxygenase-1 enzyme inhibition.

Qian Yu _et al._ (2013) identified phenolic compounds in the leaves of _Aquilaria sinensis_ and identified twenty-one compounds, including xanthones, benzo-phenones and flavones.
Ekpo et al. (2013) studied the phytochemical composition of *Aframomum melegueta* and *Piper guineense* seeds and reported the presence of alkaloids, flavonoids, tannins, saponins, steroids, cardiac glycosides and terpenes. The percentage of alkaloids in *Aframomum melegueta* was higher than that in *Piper guineense*. The phytochemicals in *Aframomum melegueta* was higher than those in *P. guineense* except in phenols.

Bienvenu et al. (2014) evaluated the medicinal value of *C. procera* seeds. The mineral analysis showed that phosphorus was the most abundant element, followed by iron and potassium. Calcium and magnesium were found in low concentrations while sodium and manganese were detected in trace quantities. The phytochemical screening of crude solvent extracts revealed the presence in methanol of alkaloids, flavonoids, glycosides, saponins, steroids, tannins, triterpenoids, anthocyanins and phenols. In carbon tetrachloride steroids and tannins were not detected. Anthraquinones were absent in all the screened extracts of both solvents. Quantitative analysis of the seeds showed high alkaloid, flavonoid and phenolic concentrations while saponins and anthocyanins were detected in low quantities.

Al-Yahyai et al. (2014) studied the chemical composition of *Citrus aurantifolia* (acid lime) leaves infected with *Candidatus Phytoplasma aurantifolia* and observed significant difference when compared to normal leaves, in the levels of various phytochemicals.

Saeidi et al. (2014) reported thirty-one components in the oil of *Marrubium vulgare* were identified. The major components of the essential oil were γ-Eudesmol, Germacrene, D-Citronellylformate, β-Citronellol, Geranylglutlate, Geranylformate.

Brannana et al. (2015) studied the phytochemical analysis of ten varieties of pawpaw (*Asimina triloba*) and reported the predominance of polyphenolic compounds with three phenolic acids, protocatechuic acid
hexoside, p-coumaroylhexoside, and 5-O-p-coumaroylquinic acid, and flavonols, particularly (−)-epicatechin, B-type procyanidin dimers and trimers.

### 2.3. Antisickling Activities of Plant Extracts

Plants which are used in the management of Sickle Cell Disease (SCD) and possess potential antisickling properties along with their active principles and authorities are reviewed under:-

Roots of *Pfaffia paniculata* (Amaranthaceae) which is an anti-anemic and antisickling was shown to contain Anthraquinones; aurone; betacyanins; betaxanthins; betalains; chromoalkaloids; ecdysteroids; flavonoids; protoalkaloids; saponins; steroids; triterpenes; zinc; iron; germanium; vitamins. 20-hydroxyecdysone- 20, 22-monoacetonide; oleanolic acid 3-O-β-D-glucuronopyranoside-methyl ester; oleanolic acid 3-O-β-D-glucuronopyranoside; oleanolic acid 28-O-β-D-glucopyranosyl ester 4-hydroxy-3-methoxy-benzoic acid; stigmasteryl-3-O-β-D-glucoside; β-sitosterol and daucosterol (Mazzanti and Braghiroli, 1994; Gosmann *et al.*, 2003; Mpiana *et al.*, 2007)

Whole plant extracts and roots of *Plumbago zeylanica* L. (Plumbaginaceae) which possesses antisickling, antimicrobial, antimicotic, antispasmodic, antiviral, anticancer and antioxidant properties, were reported to contain phytochemicals like, anthraquinones; flavonoids; saponins; tannins.3-biplumbagin; chloroplumbagin; chitranone; elliptone; 5-methoxyseselin; suberosin; xanthyletin; 2,2-dimethyl-5-hydroxy-6- acetylchromene; plumbagin acid; β-sitosterol; β-sitosteryl-glucoside; bakuchiol; 12- hydroxyisobakuchiol; saponaretin; isoorientin; isoaffinetin and psorealen (Vander and Lotter, 1971; Lin *et al.*, 2003; Wang and Huang, 2005; Vijayakumar *et al.*, 2006; Zhao and Lu, 2006; Adejumo *et al.*, 2010).
Fruits of *Piper guineensis* (Piperaceae) which is antisickling, pesticidal, insecticidal or insecticide synergists, antifungal, antimicrobial, antitumour, hypotension, bradycardia, immuno-modulatory, anti-ulcerogenic, contraceptive, central nervous system depression, analgesic, antipyretic, anti-inflammatory and antioxidant, was reported to contain phytochemicals like, piperine; wisanine; dihydrocubebin; guineensine; dihydro-piperlonguminine; sesamin; trichistachine and piperlonguminin (Wambebe *et al.*, 2001; Iyamu, 2002; Iyamu, 2003; Ekanem *et al.*, 2010; Ameh *et al.*, 2012; Okwute and Egharevba, 2013).

Leaves and seeds of *Phyllanthus amarus* (Euphorbiaceae) which possesses antisickling, antiviral, anti-inflammatory, anticancer, antidiabetic, anti-hypertensive, antimicrobial properties was reported to contain flavonoids; tannins; alkaloids; terpenoids; steroids; saponins and cardiac glycosides (Mpiana *et al.*, 2007; Obianume and Uche, 2009).

The Leaf, stem, roots and whole plant extracts of *Petiveria alliacea* L. (Phytolaccaceae) is antisickling, antioxidant and antimicrobial in nature has the following phytochemicals as active principles- Benzaldehyde; benzoic acid; benzyl 2- hydroxyethyltrisulphide; coumarin; isoarborinol; isoarborinol acetate; isoarborinolcinnamate; isothiocyanates; polyphenols; senfol; tannins; trithiolaniacine; S-phenylmethyl-L-cysteine sulfoxides (petiveriins A and B); S-(2 hydroxyethyl)-L-cysteines (6- hydroxyethiins A and B) (Kubec and Musah, 2001; Kubec *et al.*, 2002; Sahu *et al.*, 2012).

Leaves of *Acacia catechu* (Fabaceae) which is an anti-platelet aggregatory, antioxidant and free radical scavenging contains Phenolic acids; alkaloids; terpenes; tannins; flavonoids; 4-hydroxybenzoic acid; kampferol; quercetin; catechin; epicatechin; afzelechin; epiafzelechin; mesquitol; ophioglonin; aromadendrin and phenols (Li *et al.*, 2010; Sulaiman and Gopalakrishnan, 2013).
Leaves of *Acacia leucophloea* (Fabaceae) which is anti-platelet aggregatory, antioxidant and free radical scavenging contains Phenolic acids; alkaloids; terpenes; tannins; flavonoids; n-Hexacosanol; β-Amyrin and β-Sitosterol (Gupta *et al*., 2010; Sulaiman and Gopalakrishnan, 2013).

Leaves of *Acacia nilotica* (Fabaceae) which has antisickling, anti-platelet aggregatory, antioxidant and free radical scavenging activities was found to contain Phenolic acids; alkaloids; terpenes; tannins; flavonoids; cyanogenic glycosides; phlobetannin; cyclitols; fatty acids; seed oils, fluoroacetate; gums; nonprotein amino acids; m-digallic acid; gallic acid; protocatechuic acid; ellagic acids; leucocyanidin; (-) epicatechol; apigenin 6-8-bis-D-glucoside; rutin; pyrocatechol and (+) – catechin; (-) epigallocatechin-5,7-digallate (Malviya *et al*., 2011; Sulaiman and Gopalakrishnan, 2013).

*Acacia xanthoploea* (Fabaceae) stem and bark shows immense antisickling properties contain anthocyanins; carotenoid; coumarins (Sofowora, 2008).

The bark, root and leaf of *Adansonia digitata* L. (Bombacaceae) is an effective antisickling agent and also enhances erythrocytic count have Vitamins C and E as its active principles (Adesanya *et al*., 1988; Mpiana *et al*., 2007; Sahu *et al*., 2012).

Rhizomes and leaves of *Aframomum albiovaleum* (Zingiberaceae) possess antisickling and antimicrobial properties and is widely used for the management of SCD. The actice phytochemicals present includes, (E)-labda-8(17),12-diene-15,16-dial;(E)-β-17-epoxy-labd-12-ene-15,16-dial; methyl (E)-14,15-epoxylabd-8(17),12-dien-16-oate (Marlier *et al*.,1993; Abreu and Noronha, 1997; Mpiana *et al*., 2007; Sahu *et al*., 2012).

Leaf extract of *Alchornea cordifolia* (Euphorbiaceae) is known for its anti-inflammatory, antibacterial, anti-anaemic and anti-sickling properties.
with active phytochemicals as diisopentenyl guanidine; triisopentenyl guanidine; β-sitosterol; daucosterol; di-(2-ethylhexyl)-phthalate; acetyl aleuritolic acid; 5- methyl-4′-propenoxanthocyanidines 7-O-β-D-diglucopyranoside; guanidine alkaloids and anthocyanidines (Mpiana et al., 2007; Agnihotri et al., 2010; Okwu and Ukanwa, 2010; Sahu et al., 2012).

Rhizomes of Allium sativum L. (Alliaceae) acts as an antimicrobial, anti-inflammatory, insecticidal, antifungal, antioxidant and antisickling agent. It suppresses hemolysis and reduced membrane deformability. The active phytochemicals reported are alliin; allicin; isoalliin; γ-glutamyl-cysteine peptides; diallyl disulfide; diallyltrisulfide; 3-vinyl-4H-1,2-dithiin; 2-vinyl-3H-1,3-dithiin; S-methyl cysteine sulfoxide; dimethyl disulfide; dimethyl trisulfide; dimethyl tiosulfonate; sulfur dioxide; alkaloid; tannins; saponin; flavonoids; cardenolides; steroids with diallyl disulfide; flavonoids; carotenoids and ascorbic acid (Otunola et al., 2010).

Leaf extracts of Aloe barbadensis (Liliaceae) is a bacteriostatic, wound healing, anticancer, antisickling with active phytochemicals as anthranol; aloe-emodin; chrysophanic acid (chrysophanol); aloin (barbaloin); p-coumaric acid; aloesin; hydroxyanthraquinones; alkaloids; saponins; tannins phenols; phenylalanine; arginine; tyrosine; aspartic acid; histidine; ascorbic acid; polysaccharides; salicylic acid; vitamins B1, B6, B12; barbaloin; steroids; acemanna and emodin (Waller et al., 1978; Okpuzor et al., 2008; Nwaoguikpe et al., 2010; Jain et al., 2011).

The leaf, bark, root and fruit of Annona senegalensis (Annonaceae) are potential antisickling agents with saponins; steroids; flavonoids and cardiac glycosides as active phytochemicals (Mpiana et al., 2007; Yisa et al., 2010).

Leaf extracts of Morinda lucida (Rubiaceae) is antimalarial, antidiabetic, antihypertensive, antimicrobial, anti-spermatogenic, antioxidant and antisickling in nature. Phytochemicals identified includes digitolutein,
rubiadin 1-methyl ether, damnacanthal, alkaloids-anthraquinones, anthraquinol, alkaloids, anthraquinones, anthraquinol and phenolics (Mpiana et al., 2007 & 2010). Likewise, the leaf and stem of Parquetina nigrescens (Asclepiadaceae) is antisickling, antioxidant, anti-anemic in nature. Phytochemicals identified includes, anthraquinones, alkaloid, saponin, tannins, cardiac glycoside, amino acids, vit., B & C and folic acid (Gbadamosi et al., 2012).

Aerial part of Pelargonium xasperum (Geraniaceae) is an antioxidant with ability to bring about reversal of sickled RBC’s and to inhibit platelet aggregation. Phytochemicals identified include flavonoids, quercetin and kaempferol (Kokklou and Souleles, 1988; Tzeng et al., 1991).

Fruit juice of Persia americana (Lauraceae) acts as an antioxidant and antisickling agent. Active phytochemicals includes, phenols; saponins; flavonoids, alkaloid; sterols Isorhamnetinluteolin; rutin and quercetin; apigenin (Owolabi et al., 2010; Arukwe et al., 2012; Sahu et al., 2012).

Leaf and seeds of Sorghum bicolor (Poaceae) is an antioxidant and antisickling agent. Phytochemicals isolated includes, cyanides; alkaloids; tannins; carotenoids; cyanogenic glycosides; flavonoids; phenolic acids; chlorophyll (a and b); lycopene; β- carotene; palmitic; stearic; oleic and linoleic acid; histidine; methionine; threonine; isoleucine; phenylalanine; tryptophan; valine; sucrose; lactose; maltose; glucose; galactose; thiamine; riboflavin; niacin; vitamins A; 3-deoxy anthocyanins; cyanogenic glycoside; p-hydroxy-benzaldehyde, p-hydroxybenz- aldehyde; phenylalanine and tryptophan (Wambebe et al., 2001; Chaieb et al., 2007; Singh et al., 2012; Abugri et al., 2013).

Leaf extracts of Terminalia catappa (Combretaceae) acts as an antioxidant, antibacterial, anti- inflammatory, analgesic, aphrodisiac and an antisickling agent. Phytochemicals isolated includes, tannins (catappanin A; punicalagin; punicalin; terflavins A & B; tergallagin; tercatain; chebulagic acid;
geraniin; granatin B; corilagin); flavonoids (isovitexin; vitexin; isoorientin; rutin); triterpenoids (ursolic acid; asiatic acid; 2α,3β,23-trihydroxyurs-12en-28-oic acid); phenol glycosides; ascorbic acid; β-carotene; -tocopherol; p-hydroxybenzoic acid; m-coumaric acid; 3,4-dihydroxybenzoic acid; p-coumaric acid; gallic acid); squalene p-hydroxybenzoic acid; m-coumaric acid; 3,4-dihydroxybenzoic acid and p-coumaric acid (Moody et al., 2003a)

Stem, bark and root of Trema orientalis (Ulmaceae) acts as an antidiabetic, anti-anemic alkaloid; saponin; tannins; cardiac glycoside; methyl-swertianin; decussating; decussatin glycosides; sweroside; scopoletin; (-)epicatechin; lupeol; p-hydroxybenzoic acid; 3,4-dihydroxy benzoic acid; adian-5-en-3-one; β-sitosterol; 3-O-β-glucopyranosyl-β-sitosterol; hexacosanoic acid; (−)-ampelopsin F; (+)-catechin; (+)-syringaresinol; N-(trans-p-coumaroyl) tyramine; N-(trans-p-coumaroyl) octopamin; trans-4-hydroxy- cinnamic acid; 3,5-dimethoxy-4-hydroxyphenyl-1-O-β-D-glucoside and orientoside A (Tchamo et al., 2001; Kuo et al., 2007; Gbadamosi et al., 2012).

Fruit, leaf and stalk of Eugenia caryophyllata (Myrtaceae) possess antisickling, antimicrobial, antioxidant, antifungal and antiviral properties. Apart from these, it is also an anti-inflammatory, cytotoxic, insect repellent and anesthetic agent. Phytochemicals identified includes, Eugenol, humulene, cadinene, trans-β-caryophyllene, and caryophyllene oxide, eucalyptol, torreyol, pinene, linalool, isolimonene, viridiflorol; tannins (gallotannic acid); flavonoids (eugenin, rhamnetin, and eugenitin); triterpenoids (oleanolic acid, stigmasterol and campesterol); Fixed oil; glycosides; reducing sugars; eugenol; eugenyl acetate; β-caryophyllene and gallotannic acid (Wambebe et al., 2001; Chaieb et al., 2007; Singh et al., 2012).

The leaf extracts of Lawsonia inermis L. (Lythraceae) acts as an immuno-modulatory, antidiabetic, Hepato-protective, antioxidant, antibacterial, antifungi, antitubercular, cytotoxicity, antifertility, analgesic, molluscicidal,
antiviral, abortifacient, antisickling, anticoagulant, wound healing, nematicidal, antimalarial, antisickling agent (increases the oxygen affinity of HbSS blood). Active phytochemicals includes Lawsone (2-hydroxy-1:4 napthaquinone); gallic acid; glucose; mannitol; fats; resin; mucilage; and traces of an alkaloid; isoplumbagin; lawsaritol; 2-hydroxy-1,4-napthaquinone and isoplumbagin (Chang and Suzuka, 1982; Chaudhary et al., 2010).

The bark extracts of Entandrophragma utile (Meliaceae) is a known to act as an antiulcer, anti-allergenic, antisickling agent. Active phytochemicals isolated from the bark extracts includes, tannins; 7 , 20(S)-Dihydroxy-4, 24(28) - ergostadien-3-one and 2, 6-dimethoxy-2, 5- cyclohexadiene-1, 4-dione (Adejumo et al., 2011; Ameh et al., 2012).

Leaf extracts of Coleus kilimandschari (Lamiaceae) is an antisickling agent and is widely used for the management of SCD. Active phytochemicals includes, coleon U11-acetate; 16-acetoxycoleon U11-acetate; xanthanthusins F-K; coleon U; 8 , 9 - epoxycoleon U-quinone; xanthanthusin E; 14- deoxycoleon U; demethylcryptojaponol; - amyrin; betulic acid; -cedrol; coleon U and β-sitosterol (Mpiana et al., 2007).

Roots of Zanthoxylum macrophylla (Rutaceae) is acts as an antisickling, antibacterial, antiviral, larvicidal, anti-inflammatory, analgesic, anti-nociceptive, antioxidant, antibiotic, hepato-protective, anti-plasmodial, cytotoxic, anti-proliferative, antihelminthic and antifungal agent. Compounds isolated from root extracts includes, vanillic acid; p-hydroxybenzoic acid; p-fluorobenzoic acid; 2-hydroxybenzoic acid; Fagaramide; lupeol 2-Hydroxybenzoic acid; vanillic acid; p-hydroxybenzoic acid; p-fluorobenzoic acid; Fagaramide and lupeol (Adesina, 2005; Elekwa et al.,2005).

Root and the root bark of Zanthoxylum zanthoxyloides (Lam) (Rutaceae) acts has been reported to be antisickling, antibacterial, antihepatotoxic, anti-allergic, toothache, antitumor and antihypertensive in
nature. Antisickling properties include the reversal of sickled erythrocytes. Active phytochemicals isolated includes, cardiac glycolsides; alkaloids; saponins; tannins; flavonoids; divanilloylquinic acid; pellitorine; fagaronine; 3,4-O-divanilloylquinic acids; 3,5-O-divanilloylquinic acids; 4,5-O- divanilloylquinic acids; 2-hydroxymethyl benzoic acid; 2-hydroxy-3-phenylpropionic acid; vanillic acid; p-coumaric acid; caffeic acid; ferulic acid; p-Hydroxybenzoic acid; zanthoxylol; divanilloylquinic acid; pellitorine; fagaronine and 2- hydroxymethyl benzoic acid (Elekwa et al., 2005; Ejele et al., 2012; Ameh et al., 2012; Adegbolagun and Olukemi, 2010).

The leaf extracts of *Vernonia amygdalina* (Asteraceae) is an antimalarial, antidiabetic, antioxidant, antisickling agent. The phytochemicals isolated from the extracts of leaves showed the presence of vitamin C; riboflavin; n-Hexadecanoic acid; stigmasterol; chondrillasterol; succinic acid; vernodalinol; cynaroside; Stigmasterol; docosanoic acid; uracil; edotides; steroid glucosides; saponins; alkaloids; terpenes; steroids; coumarins; phenolic acids; lignans and xanthones (Gbadamosi et al., 2012).

Root extract of *Cissus populnea* (Vitaceae) is an antioxidant and acts as an antisickling agent. Compounds isolated from the root extracts are, alkaloids; flavonoids; saponins; tannins; anthraquinone derivatives (physcion and chrysaphanol); steroidal glycosides; cardiac glycosides; alkaloids; flavonoids; saponins and tannins (Moody et al., 2003a; Simeone et al., 2012; Soladoye and Chukwuma, 2012).
2.4. Epilogue

Henceforth, most of the recognized and renowned anticancer, antitumor, anti-inflammatory, antibacterial, antimalarial, antifungal and antiviral, antidiabetic, immuno-modulatory and antioxidant phytochemicals play significant role in the management of SCD, particularly in alleviating the “crisis stage” of the disease. Further research in this area ought to emphasize on-

a) Studying and earmarking the antisickling propensities of novel plants species.

b) Phytochemical analysis of these plants species.

c) Ascertaining the interaction of these compounds with the human blood components including sickled haemoglobin (HbS), red blood cells (RBC) and white blood cells (WBC), at the molecular level, in order to achieve better formulation and administration techniques for use in SCD management.