body weight. The tested plant extracts displayed appreciable level of antioxidant activities by different assay methods: the ferric thiocyanate (FTC) method (26.42±1.75-56.46±2.83%), the thiobarbituric acid (TBA) method (18.43±1.67-48.17±2.19%), reducing power method (22.76±1.87-68.45±1.07%) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging method (26.23±0.94-66.12±1.41% inhibition). Quantitative phytochemical analysis of the extracts revealed the presence of Alkaloids (0.11±0.02-0.34±0.05%), Saponins (0.18±0.02-6.01±0.88%), Tannins (0.04±0.01-14.15±0.73%), Glycosides (0.002±0.001-0.113±0.040%), Phenols (0.02±0.01-0.21±0.02%), Flavonoids (0.012±0.003-0.433±0.170%), and Steroids (0.003±0.001-0.011±0.003%). Therefore, the results indicate that extracts of Cleome rutidosperma possess significant antidiabetic and in vitro antioxidant activities. They are also rich in phytochemicals.

Keywords: Antihyperglycemic effects, antioxidant, Cleome rutidosperma, phytoconstituents, Senecio biafrae and STZ-induced diabetes

INTRODUCTION

Diabetes Mellitus (DM) is a metabolic disorder characterized by hyperglycemia, lipoprotein abnormalities, raised basal metabolic rate, defect in enzymes and high oxidative stress induced damage to pancreatic beta cells (Sharma et al., 2010). It is also characterized by polyuria, albuminuria, renal enlargement and an increase in serum creatinine value (Sassy-Prigent et al., 1995). Diabetes is becoming the third common killer of mankind, after cancer and cardiovascular disease, because of its high prevalence, morbidity and mortality (Li et al., 2004). The presence of DM confers increased risk of many devastating complications such as cardiovascular disease, peripheral vascular disease complications such as coronary artery disease, stroke, neuropathy, renal failure, retinopathy amputations and blindness.

Several distinct types of diabetes mellitus exist and are caused by a complex interaction of genetics and environmental factors (Chithra et al., 2010). According to the World Health Organization estimate 3% of the world’s populations (194 million) have diabetes and is expected to double (6.3%) by the year 2030 (Wild et al., 2004) and much of this increase occurs in developing countries due to population growth, ageing, unhealthy diet, obesity and sedentary lifestyle (WHO, 2002) and in Nigeria, diabetes was found to be as high as 23.4% among the upper class socioeconomic group and 16% among the lower class socioeconomic group (Nwafor and Owhoji, 2001).

From ancient period, people have been using medicinal plants for the treatment of diabetes and WHO estimates that 80% of the populations presently use herbal medicine for primary health care (Atmakuri and Dathi, 2010). Anti-diabetic plants have the ability to restore the function of damaged pancreatic tissue by increasing the insulin or inhibiting the intestinal absorption of glucose (Malviya et al., 2010). Administration of appropriate antioxidants from plant source could prevent or retard the diabetic complications to some extent (Muthulingam, 2010).

Corresponding Author: I.O. Okoro, Department of Biochemistry, Ahmadu Bello University, Samaru Zaria, Nigeria
Based on the WHO recommendations, hypoglycemic agents of plant origin used in traditional medicine are important. Plant drugs and herbal formulation are frequently considered to be less toxic and free from side effects than synthetic ones (WHO, 1985). Thus, the medicinal plants may provide the useful source of new oral hypoglycemic compounds for the development of pharmaceutical entities or as dietary adjunct to existing therapies (Kavishankar et al., 2011).

Plants are endowed with various phytochemical molecules such as vitamins, terpenoids, phenolic, lignins, stilbenes, tannins, flavonoids, quinones, coumarins, alkaloids, amines, betalains and other metabolites which are rich source of free radical scavengers (Zheng and Wang, 2001; Cai et al., 2003; Gracelin et al., 2012). They are also antioxidant compounds which possess anti-inflammatory, antitumour, antimutagenic, anticarcinogenic, antibacterial and antiviral activities (Sala et al., 2002; Gracelin et al., 2012). Ingestion of natural antioxidants has been associated with reduced risks of cancer, cardiovascular disease, diabetes and other diseases associated with ageing (Ashokkumar et al., 2008). Phytochemicals isolated from plant sources have been used for the prevention and treatment of cancer, heart disease, diabetes mellitus and high blood pressure (Waltner-Law et al., 2002).

Cleome rutidosperma DC is a low-growing herb, up to 70 cm tall, found in waste grounds and grassy places with trifoliolate leaves and small, violet-blue flowers, which turn pink as they age. The plant is native to West Africa, from Guinea to Nigeria, Zaire and Angola. It has become naturalized in various parts of tropical America as well as Southeast Asia (Waterhouse and Mitchell, 1998). It is commonly known as Spider plant or fringed spider flower with local names of "garseya" (in Hausa), "akidimíjọ" (Igbo) and "ẹtare" (Yoruba), in Nigeria. Cleome rutidosperma has been well studied by different researchers. The analgesic, antipyretic, anti-inflammatory, locomotory, antimicrobial, diuretic, laxative, antioxidant and antiplasmoidal activities of the plant have already been reported (Bidla et al., 2004; Bose et al., 2004, 2005, 2006, 2007, 2008, 2010). Cleome rutidosperma is traditionally used in the treatment of paralysis, epilepsy, convulsions, spasm, ear-ache, pain and skin disease (Burkill, 1985). However, there is paucity of literature on the anti-diabetic potential of this plant.

Senecio biafrae (Oliv. and Hiern), also known as English spinach is a perennial climbing herb which naturally occurs in African forest zones, from Guinea to Uganda. It’s local names in Nigeria are: “ota eke” (Igbo) and “woroworo” or “ọrọwọ” (Yoruba). It is one of the green leafy vegetables consumed in Sierra Leone, Ghana, Benin Republic, Nigeria, Cameroon and Gabon (Adebooye, 2004). Also, leaves of Senecio biafra contain various secondary metabolites such as dihydroisocoumarins, terpenoids, sesquiterpenes or amino acids (Dairo and Adanlawo, 2007; Tabopda et al., 2009). It is equally known for its therapeutic virtues, notably in Nigeria where it is used in the treatment of diabetes or pulmonary defects (Burkill, 1985; Iwu, 1993; Adebayo, 2009). The leaves and stems of the plant are used either macerated in water or in palm wine by traditional healers of our locality to treat cases of women infertility (Lienou et al., 2010). Although, the medicinal properties of this plant have been extensively studied, its anti diabetic property is largely unknown.

Therefore, this study was undertaken to evaluate the antihyperglycemic effectiveness of four different solvent extracts of Cleome rutidosperma leaves and Senecio biafrae roots in STZ-induced diabetic mice as well as the in vitro antioxidant activities and phytochemical constituents of the extracts.

MATERIALS AND METHODS

Chemicals: Streptozotocin and Glibenclamide were purchased from Sigma chemicals (St Louis U.S.A). All other chemicals and reagents used were of analytical grade.

Plant materials: The plants (Cleome rutidosperma and Senecio biafrae) were collected from Abraka in Delta State, Nigeria and Akoko in Ondo State, Nigeria, respectively. They were identified by Dr. H.A. Akinnobosun of the Herbaruim Unit, Department of Plant Science, University of Benin, Benin City, Edo State-Nigeria, where voucher specimens were deposited with numbers: UBHe0148 and UBHs0149.

Experimental animals: Mice weighing 25-35 g were obtained from National Veterinary Research Institute (NVRI) Vom, Jos, Plateau State, Nigeria. The animals were allowed 3 weeks of acclimatization before commencement of experiment. They were fed on standard laboratory diet (from Vital Feed Nig. Ltd, Jos Nigeria) and water ad libitum throughout the experiment.

Treatment and extraction of plant samples: The plant samples were washed with distilled water and air-dried at room temperature, cut into small pieces and pulverized into fine powder using pestle and mortar. They were sequentially extracted with solvents of increasing polarity (petroleum ether, acetone, ethanol and water), using the method of Arokiyaraj et al. (2009), as published by Jeyaseelan et al. (2011). Fifty grams powder of the plant was initially soaked in 200 mL of petroleum ether in airtight conical flask with daily shaking for three days at room temperature and were first filtered through doubled layered muslin cloth and then filtered through Whatman No 1 filter paper and the filtrates were collected into airtight bottles. The...
petroleum ether was removed from the filtrate under reduced pressure using rotary evaporator at low temperature. The residue was dried and used for the acetone extraction followed by ethanol and water using procedure similar to the one carried out for the petroleum ether extraction. The crude extracts were stored in refrigerator at 4°C until used.

**Induction of experimental diabetes:** Streptozotocin was dissolved in 10 mM citrate buffer pH 4.5 (Archana et al., 2001). The mice (diabetic control and test mice) were injected intra-peritoneally with portions (1 μL/g) of this solution at a dose of 60 mg per kg body weight after an overnight fast. 3 days after induction of diabetes, the mice with plasma glucose more than 200 mg/dL were considered as diabetic mice and were allowed for 2 weeks diabetic stabilization before being used for the experiment.

**Quantitative phytochemical analysis:** The different solvent extracts were subjected to quantitative phytochemical tests to determine the secondary metabolites present therein using standard procedures. Alkaloid and Flavonoids determinations were done using Harborne (1973) method; Tannin determination of Saponin by Obdoni and Ochuko (2001) method; evaluation of Glycosides was by the method described by El-Olemy et al. (1994). Phenolic Compounds by Hagerman et al. (2000) method and estimation of Steroids was done by the method of Evans (1996).

**In vitro antioxidant properties of extracts:** The *In vitro* antioxidant activities of plant extracts were done by different standard assay methods. The Ferric Thiocyanate (FTC) assay was carried out as described in the method of Osaka and Namiki (1981); Thiobarbituric Acid (TBA) assay by the method of Ottolenghi (1959); Reducing power was done according to the method described Oyaizu (1986), while the DPPH radical scavenging assay was by the method of Liyana-Pathiranan and Shahidi (2005).

**Acute toxicity studies (LD₅₀):** Acute toxicity studies of the plants extracts were conducted to ascertain the safe doses of the plant extracts to be administered to animals in this study. Oral LD₅₀ determination was done by the method of Lorké (1983) using 13 rats. The median Lethal Dose (LD₅₀) was then calculated.

**Evaluation of antihyperglycemic activity of the extracts:** The assay of the antihyperglycemic activity of the four extracts of each plant involved administration of single dose of 500 mg/kg body weight of the extracts using mice weighing 25 to 35 g. Forty mice were randomly allocated to negative/positive control and treatment groups of five mice each as follows:

- **Group I:** Normal untreated mice
- **Group II:** Diabetic control mice
- **Group III:** Diabetic+standard drug
- **Group IV-VII:** Diabetic mice given 500 mg/kg body weight of the different extracts of *Cleome rutidosperma*

The groupings above were repeated for the extracts of the second plant (*Senecio biafrae*).

Fasting blood glucose concentration was first determined in overnight fasted mice by the enzymatic glucose oxidase method using a commercial glucometer (Accu-chek® Active, Roche diagnostic, Mannheim, Germany), following which the plant extracts were administered orally using gastric cannula. Blood glucose values were then estimated hourly for 6 h. The control group (II), received distilled water in place of the extract. Similarly, a standard antidiabetic drug (Glibencamide 600 μg/kg) was administered orally to the group III animals and glucose determined at the same time intervals for the same duration according to the procedure of Aderibigbe et al. (2001).

**Statistical analysis:** Data are reported as mean±SD and were analyzed statistically using One way ANOVA followed by Tukey kramer multiple comparison test and values of p<0.05 were considered significant.

### RESULTS

**Phytoconstituents of *Cleome rutidosperma* and *Senecio biafrae***: The quantitative phytochemicals in different extracts of the plants are shown in Table 1.

| Plant/Extract | Alkaloids (%) | Saponins (%) | Tannins (%) | Glycosides (%) | Phenol (%) | Saponins (%) | Tannins (%) | Steroids (%) |
|---------------|---------------|--------------|-------------|----------------|------------|--------------|-------------|--------------|
| AQCR          | 0.29±0.01     | 3.11±0.89    | 12.03±0.81  | 0.03±0.0098    | 0.18±0.01  | 0.13±0.07    | 0.004±0.002  |
| ECR           | 0.18±0.02     | 4.12±0.81    | 10.44±0.95  | 0.004±0.004    | 0.21±0.02  | 0.31±0.078   | 0.011±0.003   |
| ACR           | 0.27±0.01     | 6.01±0.88    | 14.15±0.73  | 0.011±0.004    | 0.10±0.02  | 0.26±0.079   | 0.003±0.002   |
| PCR           | 0.11±0.02     | 2.31±0.50    | 5.48±0.89   | 0.002±0.001    | 0.14±0.02  | 0.18±0.058   | 0.004±0.002   |
| AQSB          | 0.26±0.02     | 0.81±0.13    | 0.05±0.02   | 0.115±0.040    | 0.04±0.01  | 0.35±0.006   | 0.011±0.002   |
| ESB           | 0.31±0.04     | 0.22±0.03    | 0.11±0.02   | 0.053±0.017    | 0.04±0.02  | 0.011±0.003   | 0.021±0.005   |
| ASB           | 0.34±0.05     | 0.33±0.09    | 0.04±0.01   | 0.073±0.026    | 0.02±0.01  | 0.021±0.008   | 0.003±0.001   |
| PSB           | 0.28±0.04     | 0.18±0.02    | 0.04±0.02   | 0.030±0.008    | 0.03±0.01  | 0.012±0.003   | 0.004±0.001   |

Values are mean of three determinations±SD; Values with different superscript down the column differ significantly (p<0.05); Where: AQCR = Aqueous Extract of *Cleome rutidosperma*; ECR = Ethanol extract of *Cleome rutidosperma*; ACR = acetone extract of *Cleome rutidosperma*; PCR = Petroleum ether extract of *Cleome rutidosperma*; AQSB = Aqueous extract of *Senecio biafrae*; ESB = Ethanol extract of *Senecio biafrae*; ASB = Acetone extract of *Senecio biafrae*; PSB = Petroleum ether extract of *Senecio biafrae*. 

125
The highest concentration of saponins was found in ECR followed by PCR, AA, AQCR, ESB, ASB, PSB, and ACR, respectively. The highest concentration of glycosides found in ASB and ACR, respectively. The highest concentration of tannins found in ASB and ACR, respectively. The highest concentration of phenol was found in ASB (0.02±0.01%), while ECR also had the highest concentration of phenol (0.21±0.02%) and lowest was in PCR (0.002±0.001%). Similarly, 0.433±0.170% was the highest concentration of flavonoids in ASB, while ECR had the highest concentration of flavonoids and steroids found in ASB, ESB, and AQCR, respectively.

**Antioxidants activity in different extracts:** Results for the in vitro antioxidant activity by the FTC method are shown in Fig. 1. There was significantly (p<0.05) higher activity by AA compared to all other extracts. The antioxidant activity of AA was significantly (p<0.05) higher than all extracts.

Similarly, results for the antioxidant activity by the TBA method shown in Fig. 2 reveals significantly (p<0.05) higher activity by PSB when compared to all other extracts. Also, ACR was significantly (p<0.05) lower in activity compared to all other extracts. The antioxidant activity of AA was significantly (p<0.05) higher than all extracts.

**Reducing power measurement:** The reducing power of different extracts of the two plants is shown in Fig. 3. The petroleum ether extract of *Senecio biafrae* (PSB) had the highest value among the extracts of the plants examined, followed by ASB in the order:

ASB>AQCR>PSB>ACR>AQSB>ECR>PCR
Fig. 4: In vitro DPPH Radical scavenging activities of plants extracts; Where: AQCR= Aqueous Extract of *Cleome rutidosperma*; ECR = Ethanol extract of *Cleome rutidosperma*; ACR = Acetone extract of *Cleome rutidosperma*; PCR = Petroleum ether extract of *Cleome rutidosperma*; AQSB = Aqueous extract of *Senecio Biafrae*; ESB = Ethanol extract of *Senecio Biafrae*; ASB = Acetone extract of *Senecio Biafrae*; PSB = Petroleum ether extract of *Senecio Biafrae*; AA = Ascorbic Acid

PSB>ASB>PCR>ECR>AQSB>AQCR>ACR>ESB

**DPPH radical scavenging activity:** To evaluate the antioxidant activity of the different extracts of the plants, the radical scavenging capacity based on DPPH assay was determined and the results are shown in Fig. 4. The percentage of scavenging effect on the DPPH radical was increased with the increase in the concentrations of the extract from 0.05 -1 mg/mL. The percentage of inhibition of the DPPH radical was varied from 11.61±1.08 % to 58.58±1.58% (in 0.05mg/mL to 1 mg/mL of the aqueous extract of *Cleome rutidosperma* -AQCR), 29.23±1.33% to 66.12±1.41% for ECR, 28.75±1.32% to 56.78±1.19% for ACR and 25.4±1.67% to 47.83±1.30% for PCR, while percentage inhibition for *Senecio biafrae* extracts were: 14.05±0.78% to 50.88±1.08% for AQSB, 17.72±1.29% to 42.15±1.30% for ESB, 10.43±1.71% to 26.23±0.94% for ASB and 16.09±0.74% to 39.47±0.68% for PSB. The extracts at all concentrations showed lower percentage of inhibition of free radicals than the standard drug, Ascorbic acid (87.21±0.82%-99.46±2.54% in the concentration of 0.05-1 mg/mL).

**Acute effect of oral administration of 500 mg/kg body weight of different extracts of *Cleome rutidosperma* or *Senecio biafrae* on Fasting Blood Glucose (FBG) in streptozotocin-induced diabetic mice:** To investigate the antidiabetic potential of the plant extracts-*Cleome rutidosperma* (leaves) and *Senecio biafrae* (roots), different solvent extracts were administered to STZ-induced diabetic mice and their blood glucose lowering effects was monitored for (6) h. Acute toxicity was tested up to a high concentration of 5 g/kg. Extracts tested did not cause any mortality up to a dose of 5 g/kg body weight. Even at this high dose there were no gross behavioral changes and the rats did not exhibit any sign of toxicity.

Changes in the levels of blood glucose in normal, diabetic control and experimental groups after oral administration of 500 mg/kg body weight of different extracts of *Cleome rutidosperma* are shown in Fig. 5. Diabetic control mice showed a significant increase (p<0.05) in blood glucose at 60 min after treatment. In animals treated with petroleum ether, acetone, ethanol and water extracts, the blood glucose level were significantly (p<0.05) decreased from the 60 min up 360 min post treatment when compared with the FBG.

![Graph showing blood glucose levels](image-url)

**Fig. 5: Acute antihyperglycemic activity of different extracts of *Cleome rutidosperma* and glibenclamide on blood glucose level of STZ-induced diabetic mice**
Fig. 6: Acute antihyperglycemic activity of different extracts of *Senecio biafrae* and glibenclamide on blood glucose level of STZ-induced diabetic mice

**Table 2: Percentage decrease in FBG 6 hours after treatment with 500 mg/kg of different extracts and 600 μg/kg of Glibenclamide**

| Group              | Cleome rutidosperma | Senecio biafrae |
|--------------------|---------------------|-----------------|
| Normal control     | 1.27±3.09           | 2.406±1.68      |
| Diabetic control   | -3.73±1.82          | -2.02±2.62      |
| Pet. Ether Extract | 29.70±16.27         | 10.65±6.36      |
| Acetone extract    | 28.78±15.46         | 14.07±6.94      |
| Ethanol extract    | 35.92±15.33         | 16.56±7.22      |
| Aqueous extract    | 40.86±15.61         | 19.85±7.65      |
| Glibenclamide      | 22.64±14.53         | 21.34±7.95      |

Values are mean of five determinations±SD; *: Values with different superscripts down the column differ significantly (p<0.05); Negative value means an increase in FBG at 0 h. The maximum blood glucose lowering effect on diabetic mice, as compared to the diabetic control group of animals was observed with water extract at the 6 h. The percentage blood glucose reduction (Table 2) of the different extracts at the 6 h were 29.73, 28.80, 35.95 and 40.88% for petroleum ether, acetone, ethanol and water, respectively, while standard drug, glibenclamide reduced the blood glucose level by 22.68%. The extracts had greater blood glucose lowering effect than the standard drug, glibenclamide.

DISCUSSION

The use of herbal medicine is a common practice in many countries, particularly in Asia (Chacko, 2003) and Africa (Shapiro and Gong, 2002). The currently available drug regimens for management of diabetes mellitus have certain drawbacks and therefore, there is a need to find safer and more effective antidiabetic drugs (Grover *et al.*., 2002; Rajagopal and Sasikala, 2008).

The quantitative estimation of the percentage crude yields of chemical constituents of the plant extracts showed that the leaves of *Cleome rutidosperma* and roots of *Senecio biafrae* were rich in alkaloids, saponins, tannins, glycosides, phenols, flavonoids and steroids. Mondal *et al.* (2009a) had reported from preliminary phytochemical screening, the presence of terpenoids, flavonoids, tannins and saponins in ethanolic extract of the root of *Cleome rutidosperma*. Also, Edeoga *et al.* (2005) reported the quantitative phytoconstituents(alkaloids, phenols, tannin, flavonoid and saponin) for aqueous leaves extract of *Cleome rutidosperma*. Similarly, the quantitative phytochemical concentration reported for the ethanolic root extracts for *Senecio biafrae* by Gbadamosi *et al.* (2012) were alkaloids, tannins, β Carotene, saponins, flavonoids, steroids, cardenolides, antheraquiones and glycosides. Ajiboye *et al.* (2013) also found alkaloids, saponin, tannin, phenol, flavonoids and glycosides from quantitative estimation of aqueous leaves extract of *Senecio biafrae*. However, there has not been comparative study on the different extracts evaluated in this report for the two plants. There were slight differences in this study from previous reports in proportion of phytochemicals of the extracts. This may be due to environmental conditions which are mostly based on the nature of the soil and nutrient level of the plant and environmental pollutants (Ubani *et al.*, 2012).
Phytochemical compounds in plants have been reported to be responsible for antidiabetic activities of medicinal plants (Bnouham et al., 2006; Kumar et al., 2011). Flavonoid and tannins isolated from antidiabetic medicinal plants have been found to stimulate secretion of or possess an insulin like-effect (Marles and Farnsworth, 1995).

The present study indicated high in vitro antioxidant activities of the plant extracts, which may be responsible for the biological properties manifested by them. Although, the comparative study of antioxidant activity between ethanolic and aqueous extract of *Cleome rutidosperma* has been reported (Chakraborty and Roy, 2010) and aqueous leaves extracts of *Senecio biafrae* by Adefegha and Oboh (2011), no comparative analysis has been done on the extracts reported in this study for the plants.

Various methods have been used to monitor and compare the antioxidant activity of plants. These methods differ in terms of their assay principles and experimental conditions. In different methods particular antioxidants have varying contributions to total antioxidant potential (Katalinic et al., 2006). The antioxidant activity of plants has also been attributed to the presence of phenolic hydroxyl or methoxyl groups, flavones hydroxyl, keto groups, free carboxylic groups and other structure features (Patt and Hudson, 1990).

Increased oxidative stress associated with reduction in the antioxidant status has been postulated: Oxygen free-radical can initiate peroxidation of lipids, which in turn stimulates glycation of protein, inactivation of enzymes and alteration in the structure and function of collagen basement and other membranes and play a role in the long term complication of diabetes (Sabu and Kuttan, 2002; Boynes, 1991; Collier et al., 1990).

The oral minimum lethal dose (LD$_{50}$) of the aqueous extracts of both *Cleome rutidosperma* and *Senecio biafrae* leaves and roots respectively was estimated and were found to be >5000 mg/kg, which suggest that the extracts may have low toxicity. It has been established that any substance with LD$_{50}$ estimate greater than 2000 mg/kg body weight by oral route may be considered of low toxicity and safe in humans (Bruce, 1987). Mondal et al. (2009b) reported the LD$_{50}$ ethanolic extract of the roots of *Cleome rutidosperma* to be >3000 mg/kg body weight and Bose et al. (2012) found the the LD$_{50}$ of the aqueous extract of the aerial parts of *Cleome rutidosperma* to be >2000 mg/kg b.w.

The study revealed that the leaves extract of *Cleome rutidosperma* and root extracts of *Senecio biafrae* caused significant reduction in the blood glucose level for all extracts tested in STZ-induced diabetic mice, this observation is in line with the work of Mondal et al. (2009b) who reported the hypoglycaemic activity from the ethanolic extract of *Cleome rutidosperma* roots. To the best of our knowledge, no report exist for antidiabetic activity of *Senecio biafrae*.

Comparatively, the most significant reduction of blood glucose level was observed in the aqueous extract of *Cleome rutidosperma* leaf, which was followed closely by the ethanolic extract. Similar trend was also observed in the extracts of *Senecio biafrae* root. Interestingly, the phytoconstituent and in vitro antioxidant evaluations reveals higher concentrations of flavonoids, alkaloids and glycosides for the aqueous extract of *Cleome rutidosperma*, while glycosides, saponins, phenols and flavonoids where highest for the aqueous extract of *Senecio biafrae*. Also, high antioxidant activities were displayed by the aqueous extracts of both plants compared to other extracts.

These variation(s) in concentration and composition of phytochemicals in different extracts of the plants could be responsible for their differences in blood glucose lowering effect. The antihyperglycemic activities of plant extracts have been attributed to the presence of tannins, phenols, steroids, terpenoids and alkaloids (Manickam et al., 1997; Akowuah et al., 2002). The plausible mechanism of action of these plants are still unclear but may be elucidated in ongoing research on these plants.

CONCLUSION

In conclusion, the present results confirmed that the different extracts of *Cleome rutidosperma* (leaves) and *Senecio biafrae* (roots) are rich in phytochemicals and highly valuable source of natural antioxidants and free radical scavengers. Also, the results confirm the antihyperglycemic effect of *Cleome rutidosperma* and *Senecio biafrae* extracts when administered to STZ-induced diabetic animals which suggest the presence of biologically active components which may be worth further investigation and elucidation. Further studies are in fact currently under way to determine the chronic toxic effects of the crude extracts.

ACKNOWLEDGMENT

Financial support from the Delta state University, Abraka and Education Trust Fund (ETF), is gratefully acknowledged. We thank Dr. H. A. Akinnobosun of the Herbarium Unit, Department of Plant Science, University of Benin, Benin City, Edo State-Nigeria for identification of the plants. Also, we acknowledge the technical staff of the Departments of Biochemistry, Pharmacology and therapeutics and the Nutrition unit of Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria for their technical assistance.

REFERENCES

Adebayo, A.G., 2009. Inventory of antidiabetic plants in selected districts of Lagos State, Nigeria. J. Ethnopharmacol., 121: 135-139.
Adebooye, O.C., 2004. Senecio Biafrae (Oliv. and Hiern). In: Jeffrey, C. and G.J.H. Grubben (Ed.), Denton O.A. PROTA, Wageningen, Netherlands.

Adefegha, S.A. and G. Oboh, 2011. Cooking enhances the antioxidant properties of some tropical green leafy vegetables. Afr. J. Biotechnol., 10(4): 632-639.

Aderibigbe, A.O., T.S. Emudianughe and A.S. Lawal, 2001. Evaluation of the anti-diabetic action of Mangifera indica in rats. Phytother. Res., 15: 456-458.

Ajiboye, B.O., E.O. Ibukun, G. Edobor, A.O. Ojo and Aderibigbe, A.O., T.S. Emudianughe and A.S. Lawal, 2001. Qualitative and quantitative analysis of phytochemicals in Senecio biafrae leaf. Int. J. Inv. Pharm. Sci., 1(5): 428-432.

Akowuah, G.A., A. Sadikun and A. Mariam, 2002. Flavonoid identification and hypoglycemic studies of butanol fraction from Gynura procumbens. Pharm. Biol., 40: 405-410.

Arokiyaraj, S., K. Perinbam, P. Agastian and R. Mohan Kumar, 2009. Phytochemical analysis and antibacterial activity of Vitex agnus-castus. Int. J. Green Pharm., 3(2): 162-164.

Ashokkumar, D., U.K. Mazumder, M. Gupta, G.P. Bose, A., S. Mondal and J.K. Gupta, 2008. Antioxidant and free radical scavenging activities of Oxystelma esculentum in various in vitro models. J. Comp. Integ. Med., 5(1): 1-6.

Atmakuri, L.R. and S. Dathi, 2010. Current trends in herbal medicines. J. Pharm. Res., 3: 109-113.

Bidla, G., V.P.K. Titanji, B. Joko, G. El-Ghazali, A. Legssyer, 2006. Medicinal plants with potential antidiabetic activity: A review of ten years of herbal medicine research (1990-2000). Int. J. Diabetes Metab., 14: 1-25.

Boynes, J.W., 1991. Role of oxidative stress in the development of complication in diabetes. Diabetes, 40: 405-411.

Bruce, R.D., 1987. A confirmatory study of the up-and-down method for acute oral toxicity testing. Fundam. Appl. Toxicol., 8: 97-100.

Burkill, H.M., 1985. The Useful Plants of West Tropical Africa. 2nd Edn., Royal Botanic Gardens, Kew, Richmond, United Kingdom, 1: 960.

Chacko, E., 2003. Culture and therapy: Complementary strategies for the treatment of type-2 diabetes in an urban setting in Kerala, India. Soc. Sci. Med., 56: 1087-1098.

Chakraborty, A.K. and H.K. Roy, 2010. Evaluation of anti-arthritic activity of betalains from plants of the Amaranthaceae. J. Agr. Food Chem., 58(1): 2288-2294.

Chitra, V., P.V. Varma, M.V. Raju and K.J. Prakash, 2010. Study of antidiabetic and free radical scavenging activity of the seed extract of Strychnos nuxvomica. Int. J. Pharm. Sci., 2: 106-110.

Collier, A., R. Wilson, H. Bradley, J.A. Thomson and M. Small, 1990. Free radical activity in type 2 diabetes. Diabetes, 7: 27-30.

Dairo, F.A.S. and I.G. Adanlawo, 2007. Nutritional quality of Crassocephalum crepioides and Senecio biafrae. Pak. J. Nutr., 6(1): 35-39.

Edeoga, H.O., D.E. Okwu and B.O. Mbaebie, 2005. Phytochemical constituents of some Nigerian medicinal plants. Afr. J. Biotechnol., 4(7): 685-688.

El-Olemy, M.M., F.J. Al-Muhtadi and A.F.A. Afifi, 1994. Experimental Phytochemistry: A Laboratory Manual. King Saud University Press, Saudi Arabia, pp: 21-27.

Evans, W.C., 1996. Trease and Evans Pharmacognosy. 14th Edn., Bailiere Tindal W.B. Saunders Co., Ltd., London, pp: 224-575.
Gbadamosi, I.T., A.E. Aliya and O. Okolosi, 2012. In-vitro antimicrobial activities and nutritional assessment of roots of ten Nigerian vegetables. New York Sci. J., 5(12): 234-240.

Gracelin, D.H., A.J. Britto and B.J.R. Kumar, 2012. Qualitative and quantitative analysis of Phytochemicals in five Pteris species. Int. J. Pharm. Pharm. Sci., 5: 105-107.

Grover, J.K., S. Yadav and V. Vats, 2002. Medicinal plants of India with antidiabetic potential. J. Ethnopharmacol., 81: 81-100.

Hagerman, A., I. Muller and H. Makkar, 2000. Quantification of Tannins in Tree Foliage: A Laboratory Manual. FAO/IAEA, Vienna, pp: 4-7.

Harborne, J.B., 1973. Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis. Chapman and Hall Ltd., London, pp: 278.

Iwu, M.M., 1993. Handbook of Africa Medicinal Plants. C.R.C. Press, Boca Raton, Ann Arbor Florida, USA, pp: 435.

Jeyaseelan, E.C., M.K. Pathmanathan and J.P. Jeyadevan, 2011. Inhibitory effect of different solvent extracts of Vitex negundo L. and Allium sativum L. on phytopathogenic bacteria. Arch. Appl. Sci. Res., 3(1): 1-8.

Katalinavie, V., M. Miloš, T. Kulisiæ and M. Jukiæ, 2011. Diabetes and medicinal plants: A review. Int. J. Pharm. Biomed. Sci., 2: 65-80.

Kumar, S., V. Kumar and O. Prakash, 2011. Antidiabetic, hypolipidemic and histopathological analysis of Dillenia indica (L.) leaves extract on alloxan induced diabetic rats. Asian Pac. J. Trop. Med., 4(5): 374-352.

Li, W.L., H.C. Zheng, J. Bukuru and N. Kimpe De, 2004. Natural medicines used in the traditional Chinese medical system for therapy of diabetes mellitus. J. Ethnopharmacol., 92: 1-21.

Lienou, L.L., P.B. Telefo, B. Bayala, M.D. Yemele, M.C. Lemfack, C. Mouokeu, C.S. Goka, S.R. Tagné and F.P. Moundipa, 2010. Effect of ethanolic extract of Senecio biafrae on puberty onset and fertility in immature female rat. Cameroon J. Exp. Biol., 6: 101-109.

Liyana-Pathiranan, C.M. and F. Shahidi, 2005. Antioxidant activity of commercial soft and hard wheat (Triticum aestivum L.) as affected by gastric pH conditions. J. Agr. Food Chem., 53: 2433-2440.

Lorke, D., 1983. A new approach to acute toxicity testing. Arch. Toxicol., 54: 275-287.

Manickam, M., M. Ramanathan, M.A. Jahromi, J.P. Chansouria and A.B. Ray, 1997. Antihyperglycaemic activity of phenolics from Pterocarpus marsupium. J. Nat. Prod., 60: 609-610.

Marles, R.J. and N.R. Farnsworth, 1995. Antidiabetic plants and their active constituents. Phyto medicine, 2: 137-189.

Mondal, S., G.K. Dash, S. Acharyya, A. Bose and V. Singh, 2009a. Hypoglycaemic activity from the roots of Cleome rutidosperma DC. J. Biomed., 4(1): 64-69.

Mondal, S., B.R. Mirdha and S.C. Mahapatra, 2009b. The science behind sacredness of Tulsi (Ocimum sanctum Linn.). Indian J. Physiol. Pharmacol., 53: 291-302.

Muthulingam, M., 2010. Antidiabetic efficacy of leaf extracts of Asteracantha longifolia (Linn.) Nees. on alloxan induced diabetes in male albino wistar rats. Int. J. Pharm. Biomed. Res., 1: 28-34.

Nwafor, A. and A. Owohji, 2001. Prevalence of diabetes mellitus among Nigerians in port harcourt correlates with socio-economic status. J. Appl. Sci. Envir. Manage., 5(1): 75-77.

Obdoni, B. and P. Ochuko, 2001. Phytochemical studies and comparative efficacy of the crude extracts of some homostatic plants in Edo and Delta States of Nigeria. Global J. Pure Appl. Sci., 8: 203-208.

Oyaiu, M., 1986. Studies on product of browning reaction prepared from glucose amine. Jpn. J. Nutr., 44: 307-315.

Ottolenghi, A., 1957. 2-Thiobarbituric acid (TBA) method. Arch. Biochem. Biophys., 77: 355-359.

Patt, D.E. and E.J.F. Hudson, 1990. Natural Antioxidants not Exploited Commercially. In: Huson, B.J.F. (Ed.), Food Antioxidants. Elsevier Applied Science, London, U.K., pp: 171-191.

Patt, D.E. and E.J.F. Hudson, 1990. Natural Antioxidants not Exploited Commercially. In: Huson, B.J.F. (Ed.), Food Antioxidants. Elsevier Applied Science, London, U.K., pp: 171-191.

Rajagopal, K. and K. Sasikala, 2008. Antihyperglycaemic and antihyperlipidaemic effects of Nymphaea stellata in alloxan-induced diabetic rats. Singap. Med. J., 49: 137-141.

Sabu, M.C. and R. Kuttan, 2002. Antidiabetic activity of medicinal plants and its relationship with their antioxidant property. J. Ethnopharmacol., 81: 155-160.

Sala, A., M.D. Recio, R.M. Giner, S. Manez, H. Tournier, G. Schinella and J.L. Rios, 2002. Antiinflammatory and antioxidant properties of Helichrysum italicum. J. Pharm. Pharmacol., 54(3): 365-371.

Sassy-Prigent, C., D. Heudes, S. Jouquey, D. Auberval, M.F. Belair, O. Michel, G. Hamon, J. Bariety and Bruneval, 1995. Morphometric detection of incipient glomerular lesions in diabetic nephropathy in rats. Protective effects of ACE inhibition. Lab. Invest., 73: 64-71.
Shapiro, K. and W.C. Gong, 2002. Use of herbal products for diabetes by latinos. J. Am. Pharm. Assoc., 42: 278-279.

Sharma, V.K., S. Kumar, H.J. Patel and S. Hugar, 2010. Hypoglycemic activity of Ficus glomerata in alloxan induced diabetic rats. Int. J. Pharm. Sci. Rev. Res., 1: 18-22.

Tabopda, T.K., G.W. Fotso, J. Ngoupayo, A.C. Mitaine-Offier, B.T. Ngadjui and M.A. Lacaille-Dubois, 2009. Antimicrobial dihydroisocoumarins from Crassocephalum biafrae. Plant Med., 75: 1258-1261.

Ubani, C.S., O.A. Oje, F.N.P. Ikeogwo, E.A. Eze and C.L. Okufo, 2012. Effect of varying soil minerals and phytochemical parameters on antibacterial susceptibility of Mitracarpus villosus ethanol extracts; using samples from south east and south-southern regions of Nigeria. Glob. Adv. Res. J. Microbiol., 1(7): 120-125.

Van-Burden, T. and W. Robinson, 1981. Formation of complexes between protein and Tannic acid. J. Agr. Food Chem., 1: 77.

Waltner-Law, M.E., X.L. Wang and B.K. Law, 2002. Epigallocatechin gallate: A constituent of green tea, represses hepatic glucose production. J. Biol. Chem., 277: 34933-34940.

Waterhouse, B. and A. Mitchell, 1998. Northern Australia Quarantine Strategy Weeds Target List. AQIS Miscellaneous Publication, Canberra, pp: 29.

WHO (World Health Organization), 1985. Diabetes mellitus: Report of a WHO study group. Technical Report Series, Geneva, No. 727.

WHO (World Health Organization), 2002. Non-Communicable Disease Prevention and Health Promotion. Fact Sheet-Diabetes.

Wild, S., G. Roglic, R. Sicree and H. King, 2004. Anders green: Global prevalence of diabetes. Diabetes Care, 27: 1047-1053.

Zheng, W. and S.Y. Wang, 2001. Antioxidant activity and phenolic compounds in selected herbs. J. Agr. Food Chem., 49(11): 5165-5170.