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Evaluation of *Guiera Senegalenses* on Prevention of Type 2 Diabetes Among Sudanese Adult Patients

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Abstract: *Guiera senegalensis* (GS) reflects the reduced glucose exposure of erythrocytes over a preceding time frame proportional to erythrocyte survival. GS is thus an anti-diabetic function of the glucose-time curve, an educationally useful concept to aid teaching and clinical judgment. Sixty-one newly diagnosed patients with an average age of 48.2 years and a weight of 64.9 kg have participated in the study. Participants were significantly different in their educational, socioeconomic levels, and most of them have no family history of diabetes. To evaluate the hypoglycemic effect of GS, the patients were divided into four groups (G1, G2, G3, and G4) and treated with four different doses of the aqueous extract of the herb (0.5, 1, 1.5 and 2 Oz of GS boiled for 10 minutes in 0.5-liter water). The experiment has lasted for five days for each group, and the blood glucose level of the patients was checked using GOD–POD method, at fasting (FBS), and following two hours after the breakfast (RBS). Another group of 30 patients (control) received Douniel drug (5mg/day/person) instead of the GS herb extract and checked for glucose level with the same procedure mentioned above. The results revealed that blood glucose level (mg/dl) for all patients lowered by 9% after every 24 hours of the treatment and by 35% at the end of the treatment. The average fasting and random blood glucose levels were significantly ($P<0.001$) reduced from 326.21 and 322.95 mg/dl at the start of the treatment to 213.57 and

202.87 mg/dl sequentially at the end of the treatment. The herb significantly (P<0.001) reduced the blood glucose levels, however, with negligible side effects (vomiting on two patients of group G4). Similar hypoglycemic effects on random blood sugar for both the herb extract and Daniel drugs noticed. However, the average fasting blood glucose level of patients treated with herb extract (266.21 mg/dl) was significantly (P<0.001) lower than that of patients treated with the Daniel drug (280.47 mg/dl). Accordingly, the action of this herb may be similar to that of Douniel drug. However, it might have more prolonged action than Douniel. The study strongly recommends GS as a potential herb for the treatment of type II diabetes.

1. Introduction

Diabetes mellitus is a lifelong non-communicable disease (NCD) that affect the metabolism of glucose and been characterized by persistent hyperglycemia [1]. There are two types of diabetes; Type 1, which characterised by lack of insulin due to the destruction of the beta cells of the pancreas due to an autoimmune disease. It affects mainly children and occurs in 5-10% of the diabetic patient [2]. Type 11 diabetes is characterised by resistance to the action of insulin in the target cells with or without deficiency. It affects the majority of patients and occurs due to hereditary and environmental factors [3].

Recently, diabetes and other NCDs are assuming increasing importance in the developing world. According to a recent WHO report, the number of diabetic patients in the developing world in 1995 will increase by the year 2025 by more than 3005 (90% are type 11). At the same, the expected rise in Europe will be only 44.8%. The factors that contribute to this unprecedented rise are increased prevalence of obesity, decreased physical activity, aging populations, and increased reliance on unhealthy, new, or fast foods.

Currently, in Sudan, diabetes is emerging as a disease of significant morbidity and mortality rates [4]. Some studies indicate that it is responsible for 10% of hospital admissions and mortality. The few and small-scale prevalence studies were done in 1993 indicated a crude prevalence rate of 3.4%. Since then, no statistical studies have been done. The rough impression among the professionals is that at least there is one diabetic in each Sudanese family. Type 1 is much rarer and constitutes roughly 10% of all cases [5].

Guirea senegalensis is a member of the Combretaceae family, and it is a small wild shrub of high spreading from the base, leaves simple, opposite or sub-opposite, oblong-elliptic 2.5-5 to 1.5-3.5cm, black dotted with glands on both surfaces. This plant is abundant on the sandy soil in the semi-desert areas of Kordofan, Darfur, Blue Nile, Upper Nile, and the Northern part of Bahr El-Gazal [6]. Recently, some workers investigated the therapeutic value of this herb as anti-diabetes [7], as anti-malarial [8], and as a detoxifier agent to snake venom [9, 10]. We feel that the results of these studies are encouraging that more investigations are justified. Many Sudanese diabetic patients used water extract of *G. senegalenesis* leaves for their diabetes because they see it active, available, and no side effects were shown.

The rationality of the study, some of the diabetic patients use chemical drugs that may lead to side effects such as hypoglycemia. Abdominal a beset, skin problems Many of the diabetic patients leave in rural areas where they usually go short of their drugs and might face difficulties in traveling to the near town to obtain them. Also, the herbal medicines, in general, have more acceptability to them than chemicals. Once many of the patients, especially from rural areas of deficient socio-economic status and, might not afford the cost of the chemical drugs, its relatively moderate cost.

In Kordofan, as well as in many regions in Sudan, many people use *G. senegalenesis* leaves as a treatment for diabetes mellitus. However, this use till now is not accompanied by apparent scientific approval for how much this herb is useful for diabetic patients. Accordingly, this study represents a first step towards using local herbs instead of chemical drugs as a treatment for diabetes. The specific objectives of this study were to determine the influence of Gubaish extract water extraction on an *in-vivo* study to evaluate its effects on reducing blood glucose compared with Douniel as standard drug.

2. Materials and Methods

2.1. Study area and patient's condition

This study, including all non-insulin dependent diabetes (type-11) patients who will visit the diabetic clinic (Dr. Mohammed Ahmed Omer center or diabetes, Kordofan-Sudan) within four months from the start of our study. The total number of registered patients in this centre since its establishment in 2001 is about 1700. They belong to various tribes and different socio-economic levels and geographical areas. Most of them use *G. Senegalese's* leaves (GSL) for a long time as a treatment of diabetes along with or without chemical drugs. They believe that GSL has a useful role in the treatment of diabetes. Some patients rely only on the GSL, and they enjoy a satisfactory control both clinical (i.e., absence of symptoms of hyperglycemia such as polyuria, polydipsia) and glycaemic (i.e., they have normal blood glucose levels).

2.2. Sample selection

The sample involved all the newly diagnosed diabetic who will visit the diabetic centre within four months from the start of the study. Sixty-one (61) diabetic patients; type 11 participated in this study. They were divided into four groups and treated with four different doses of *G. Senegalese's leaves* of water extract. The other 30 patients participated in the Douniel study.

2.3. Preparation of Plant material and treatment

The leaves of *G. sengalenesis* were collected from Elobeid city (Khor Taghat region) in November 2005 and dried in the shade. The leaves were coarsely powdered and weighed 0.5, 1.0,1.5, and 2.0 ounces. For the treatment, the plant material for each of the four treatments will be boiled within 0.5 litter distill water for 10 minutes. Filtered and the supernatant immediately given to fasting patients. Immediately the fasten patient will be checked for fasting blood glucose level (mg/dl). After 15 minutes of the treatment of herb extract, the patients would take the breakfast. After 2 hours of the breakfast, the patients were checked for random blood sugar. For the control, fasting blood glucose levels at the start is considered as a control. Also, the chemical drug Douniel treatment was carried out for the comparison.

2.4. Evolution of the effectiveness of fasting and random blood glucose

Glucose kits, florid tube, spectrophotometer, automatic pipette. Disposable plastic tubes and centrifuge are laboratory equipment used for testing blood sugar. Accurately, about 2.5cc blood was taken from each patient into a fluoride tube. Then, centrifuged for 3 minutes, then about 1 ml of glucose kits was transferred into two new centrifuge tubes. One used for instrument calibration. 1 ml of H2O as blank. The other one was used for testing the sample approximately10 µmL of blood with the presence of kit reagent. The value of glucose concentration was determined by the following in Equation (1):

$$Calculation = \frac{absorbance}{standard} \times 100\% \quad \cdots\cdots\cdots\cdots (1)$$

Standard concentration = mg/dL

2.5. Assessment of data collection using the Questionnaire Technique

To have an idea about the socio-economic aspects of patients who calibrate in this study, a questionnaire form was filled, including the following data which are involved; Family history; Age weight; Sex; Duration of illness; Level of education, and income. Finally, the use of *G. Senegalese's* or any other herbal as a treatment for diabetes in the study area also considered.

2.6. Data analysis

All data regards the hypoglycaemic effect of *G.senegalensis* treatments and Douniel were subjected to analysis using software SPSS.

2.7. Ethical considerations

Verbal consent was obtained from all the potential participants in our study after a full explanation of nature, included objectives and procedures of the study. It was made clear to the participants that their participation is voluntary and can quite at any stage of this study.

3. Results and discussion

3.1. Socio-economic aspects of patient groups

Table (1) shows five groups of 91 diabetic patients (type 2) who participated in this study. They are of different socio-economic levels, belonging to various tribes and originated in different geographical regions of North Kordofan state. The percentage of male to female is different from one group to another, and in general, 58% of patients are female, and 42% are male. Their average age and weight were 48.4 years 64.92 kgs, respectively.

Table 1. The sex %, age average and weight of the study groups

	n	Sex		Age	Weight
Group		M (%)	F (%)	Average ± SD	Average ± SD
G1	15	33.33	66.67	43.53±3.83	73.40 ± 8.87
G2	15	26.67	73.33	40.33±4.76	67.40 ±12.36
G3	15	60.00	40.00	48.40±4.86	64.92 ±16.98
G4	16	46.67	53.33	47.06±7.47	54.60 ±8.36
G5	30	44.83	55.17	47.44±5.30	55.40± 12.50

Abbreviations: G1, G2, G3, and **G4** represent the patient groups classified according to the dose of Gabaish treatment with doses of (0.5, 1, 1.5, 2 ounces/day) for five days respectively dependent manner. **G5**: the patient group who used Douniel as a treatment only. **Control:** patient without treatment.

In Table (2), the results also showed that the duration of illness for most patients was going to be less than one month. Only about 27% of groups G1 and G2 patients were ill for more than four weeks; this revealed that all the patients were clinically newly diagnosed with type 2 diabetes.

Table 2: Duration of illness (NIDDM) of patient groups

	Duration of illness as (%)			
Group	3 days - 2 weeks	2 - 4 weeks	4-8 weeks	8-12 weeks
G1	46	27	13	14
G2	20	53	7	20
G3	27	66	7	-
G4	33	60	-	7
G5	28	72	-	-

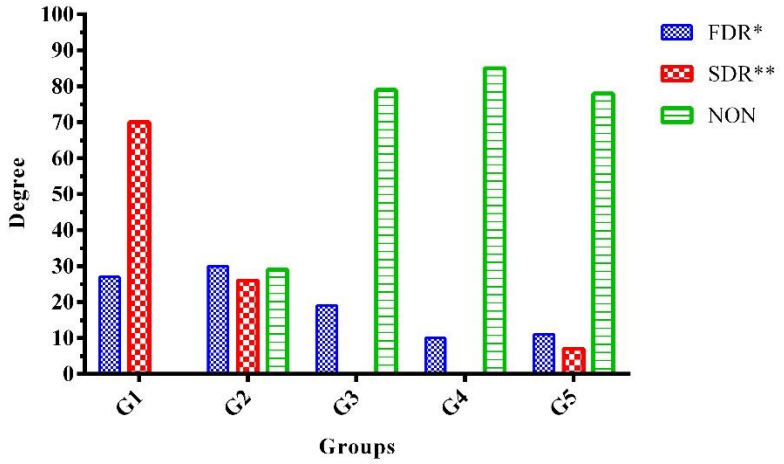

Figure 1. Family history
FDR*: First-degree relative.
SDR:** Second-degree relatives.

Figure (1) shows that the patient had no complaints of diabetic complications, and they were mostly having no history of diabetes in their families. Additionally, the result approved that 75% of the patient group are educated, as presented in Table (3). However, they are of various educational levels. The university levels represent a lower percentage (6%) of means.

Table 3: Educational levels of the study groups (as %)

Group	Khalwa	Uneducated	Literacy	Primary School	High Secondary School	University
G1	-	7	33	40	13	7
G2	-	7	27	26	33	7
G3	7	-	20	40	26	7
G4	-	47	13	13	20	7
G5	4	45	10	24	13	4

G1: Group 1, G2: Group 2, G3: Group 3, G4: Group 4, and G5: group 5.

Moreover, the result reflects that the educational level for most of the study groups is the primary school for G1 (40%), G3 40%, and high secondary school for G2. Moreover, literacy represents 33% in G1, 27% in G2, and 20% in G3. On the other hand, uneducated represent a high percentage of G4 (47%) and G5 (45%).

Furthermore, the result revealed that herbal medicines are widely used in the rural community in the treatment of diabetes. We found that *G. Senegalanesis* represent the most used herbal (70%), out of 15 types of local herbs in the treatment of diabetes. Some peoples use more than one herb as a treatment for diabetes mellitus.

3.2. The hypoglycemic effect of G. senegalensis on blood glucose level

Table 4 and Figure 2 were depicted a remarkable decrease in fasting/random (after 2 hours from breakfast and herb treatment) blood glucose level (mg/dL) in patients treated with *G. senegalensis* extract compared to 0 levels (blood glucose level before the start of herb treatments). The concentration of blood glucose (mg/dL) is lowered by a decreasing rate from the first day of herb treatments up to the 5th day, the last day of the measurement. The effect of herb treatment on blood glucose level on the first day is not significantly different.

Table 4. The effect of G. senegalensis extracts on fasting/random blood sugar (mg/dL) in type II diabetic patients

Time	N	Mean FBS (mg/dl) ± SD	Mean RBS (mg/dl) ± SD
Day1	61	326.21± 48.98 (0 level)	322.95±66.529
Day2	61	291.72±61.69***	290.00±50.39***
Day3	61	262.77±50.02***	265.13±51.84***
Day4	61	236.79 ±52.43***	241.66±47.62***
Day5	61	213.57±46.72***	202.87±50.219***

*** Significant at ($P \leq 0.001$)

The blood glucose level (mg/dL) for all patients groups is lowered by about 9 % during every night of the treatment, and about 35% during four nights of the treatments. Average fasting/random blood glucose level is reduced from 326.21/322.95 mg/dL to 213.57/202.87 mg/dL, respectively. This approved that the water extract of *G. senegalensis* leaves has a hypoglycemic effect. This herb was scientifically ($P \leq 0.001$) reduced the blood glucose levels in all herb treatments (0.5, 1.0,1.5, and 2.0 Oz of herb/0.5 litre of water) and at four nights of the treatments.

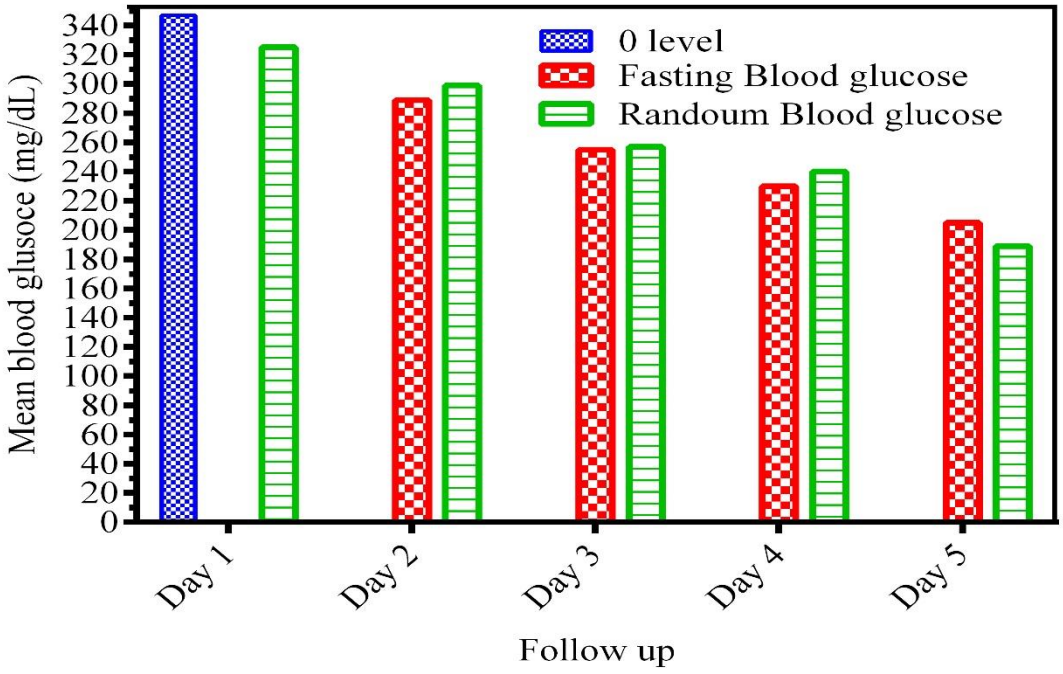

Figure 2: The effect of *G. senegalensis* extract on blood glucose levels (Fasting + Random) in type II diabetic patients within five days

This result agreed with the previous findings, which approved the hypoglycemic effect of *G. senegalensis* extracts using animal models [11]. From the results, a significant hypoglycemic effect in fasting/random blood glucose level ($P \leq 0.01$) begins from the second day. The biochemical action mediated the hypoglycemic effect of *G. senegalensis* leaves extract is still unknown. However, it may have a role similar to a one or more recently identified hypoglycemic mechanisms of some Chinese herbs [12]

- Increasing insulin secretion (ginseng, bitter melon, aloes, biophytum sensitivum);

- Enhancing glucose uptake by adipose and muscle tissues (ginseng, bitter melon, and cinnamon);
- Inhibiting glucose absorption from the intestine (Myrcia and sanzhi);
- Inhibiting glucose production from hepatocytes (berberine, fenugreek leaves).

Moreover, some of the phenolic acids have been identified in *G. Senegalensis* extract and other medicinal plants [13]. These acids are known for their potential therapeutic uses: anti-bacterial, anti-viral (HIV-1), anti-mutagenic, and inflammatory [14]. This anti-inflammatory action may improve the pancreas function for the release of insulin, enhances the overall metabolism in the body, and subsequently increases the uptake of blood glucose by different organs and tissue.

3.3. The effect of G. Singleness dosage on blood glucose level of type II diabetic patients

The effect of *G. senegalensis* on blood glucose levels in NIDDM patients was examined using four herb concentrations (0.5, 1.0, 1.5, and 2.0 ounces) for four patient groups (G1, G2, G3 & G4). In comparison to 0 levels, fasting / random blood glucose level was significantly ($P < 0.01$) reduced with over the total mean values for the four concentrations of herb treatment and through 5 days of treatment (Table 5, Table 6). The subsequent increase in herb concentration or dose was not accompanied by a subsequent decrease in blood glucose levels in both fasting and random states. However, a reversal effect has been shown; the average fasting/random blood glucose level was decreased by increasing the herb concentration in the treatment. From the result (Table 5) the average fasting/random blood level is 233.03/241.51 mg/dL and 292.33/281.86 mg/dl for G1 (0.5 oz) and G4 (2.0) treatments, respectively. This is thought to be connected to the mode of action of this herb. The hypoglycemic effect of G3 and G4 doses were not significantly different from that with Douniel. However, treatments G1 and G2 treatment have significantly resulted in a hypoglycemic effect greater than the Douniel. This fact declared that higher concentrations of Guiera senegalensis water extract reduce the hypoglycemic effect of this plant. Accordingly, a lower effective dose from the leaves extract should be determined for the proper use of this herb in the treatment of type II diabetic patients.

Table 5. The effect of G. senegalensis concentration on fasting/random Blood glucose levels (mg/dl) in comparison to Douniel

Doses	N	Mean FBS ±SD	Mean RBS ±SD
Con. 0.5 oz	75	233.03±72.09**	241.51±77.45**
Con. 1.0 oz	75	250.51±63.80**	261.07 ± 73.55**
Con. 1.5 oz	75	287.25±50.27	272.49 ± 54.69
Con. 2.0 oz	80	292.33±54.95	281.86± 55.46
Douniel	150	280.47±47.35	267.32 ± 48.56

**Significant at ($P \leq 0.01$)

No side effect of *G. senegalensis* treatment has been observed through all days of the experiment. This attributed to the low dosage of herb concentrations used in this experiment. This consistent with a previous study approved that the dose of 250 mg/kg/day of the water extract had a minor change in the internal organs of Wister albino rats compared to a dose of 500 and 1000 mg/kg/day [15]. However, people in the study area use this plant traditionally in the treatment of diabetes. If it would be safe at low concentrations, its safety after long term use needs to be approved. According to this result, the water extract of *G. senegalensis* has a hypoglycemic effect and can be used more safely at lower dose concentrations.

3.4. Comparison between G. senegalensis and Dounil treatments

In this study, the overall hypoglycemic effect of *G. senegalenesis* on fasting/random blood glucose levels of type II diabetic patients on five days was compared to the overall hypoglycemic effect for

patients treated with the standard chemical drug (Douniel). The result (Table 6) revealed that the average fasting blood glucose level of patients treated with herb (266.21 mg/dl) is scientifically ($P < 0.05$) different from that for patients treated with douniel drugs only (280.47 mg/dl). Moreover, no significant difference in overall random blood glucose levels of patients treated with *G. senegalensis* extract compared to douniel. The effect of *G. senegalensis* extract on fasting blood glucose level is more significant than effect chemical drug; Douniel. This merit of using this herb in the treatment of type II diabetes should be verified over a long term study to secure its safety for an extended user level.

Table 6. The average fasting/random blood glucose level (mg/dl) after five days of G. senegalensis and Douniel treatments.

	Study G.	N	Mean	Std. Deviation
FS-1	**G. Senegalenesis**	305	266.21*	65.400
	Douniel	150	280.47	47.346
RBS	**G. Senegalenesis**	305	264.52	67.327
	Douniel	150	267.32	48.562

FS-1: Fasting, RBS: Random, *Significant at ($P< 0.05$)

Comparing the hypoglycaemic effect of *G. senegalensis* and Douniel during five days of the treatment, a unique pattern for such one has been observed (Table 7). The reduction in fasting blood glucose level of the patient was more significant in groups received herb treatment than in the group treated with the Douniel. The effect in the case of the random state remains more or less similar for both treatments. The detailed result has been shown before in comparing the overall effect of herb treatment on fasting/random blood glucose levels compared to Douniel (Table 6, Table 7). This indicated that the action of the *G.senegalensis* effect is different from that of Douniel. The cumulative overnight effect in the reduction of fasting blood glucose levels after the second day is more significant than Douniel. Douniel is a sulphonylurease agent that lowers blood glucose by stimulating insulin release from beta cells of islet tissue in the pancreas. Therefore the Douniel action is prolonged to 24 hours [16]. Accordingly, the action of this herb may be similar to Douniel drug; however, it may have more prolonged action than Douniel.

Table 7. Comparison between *G. senegalensis* and Douniel effect on blood glucose level (mg/dl) through 5 days of treatment

	Blood glucose level (*G. senegalensis*) (*n=61*)	Blood glucose level, (Douniel) (*n=30*)
FS-	326.21±48.98	322.77±35.415
1-P	322.95±66.52	317.03±35.025
2-F	291.72±61.69**	314.33±35.592
2-P	290.00±50.39**	297.80±31.982**
3-F	262.77±50.02**	284.27±31.873**
3-P	265.13±51.84**	268.03±35.598**
4-F	236.79±52.43**	252.80±25.308**
4-P	241.66±47.62**	239.13±25.683**
5-F	213.57±46.72**	228.20±25.882**
5-P	202.87±50.21**	214.60±26.925**

*FS-1: 0 levels, 1-P: 1st day postprandial, 2-F: 2nd day fasting, 3-P: 3rd day postprandial, 4-F: 4th day fasting, and so on.

4. Conclusion

G. senegalensis herb extract significantly reduced blood glucose levels in type II diabetic patients in comparison to Douniel drug. No side effect has seen on patients treated with 0.5,1.0,1.5 Oz doses of herb extract. However, two patients (out of 16) have vomited at a dose of 2.0 Oz herb extract. Many interlaboratory tests should be conducted to confirm the result of this study; the hypoglycemic effect of *G senegalensis* on the treatment of type II diabetic patients.

Further studies should be directed on the leaves of *G. senegalensis* to identify the active ingredients that contributed to the hypoglycemic effect. Sudan is very rich in medicinal plants and shrubs. Accordingly, a multidiscipline research unit of different specialists (Biologists, Nutritionists, Biochemists, Pharmacologists, and Physicians) with a strong financial position should be found to explore the medicinal value & safety use of this plant. Health education is essential to aware people in a different part of the country about side effects in using traditionally local herb in the treatment of certain diseases. More chance should be given to the patients using traditional medicine to discuss their experience with different herbal medicine to benefit from the results and experiences.

Conflict of interest

The authors declare that there is no conflict of interest. The ethical values letter has realised by the Sudan Federal Ministry of Health on 25/4/2006. See additional file attachment.

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References

[1] Association A D 2019 2. Classification and diagnosis of diabetes: standards of medical care in diabetes—2019 *Diabetes Care* **42** S13-S28
[2] Weinstock R S 2019 Management of blood glucose in adults with type 1 diabetes mellitus. UpToDate)
[3] Kumar P and Clark M 2002 Diabetes mellitus and other disorders of metabolism *Clinical medicine* **2** 1069-71
[4] McIntyre H D 2018 Discovery, Knowledge, and Action—Diabetes in Pregnancy Across the Translational Spectrum: The 2016 Norbert Freinkel Award Lecture *Diabetes care* **41** 227-32
[5] Musa R E E 2016 Estimation of Thyroid Hormones and TSH in Type 2 Diabetic Patients in Khartoum State. Sudan University of Science & Technology)
[6] Ibrahim M A, Koorbanally N A and Islam M S 2014 Antioxidative activity and inhibition of key enzymes linked to type-2 diabetes (α-glucosidase and α-amylase) by Khaya senegalensis *Acta Pharmaceutica* **64** 311-24
[7] Shahrajabian M H, Sun W and Cheng Q 2019 Modern pharmacological actions of longan fruits and their usages in traditional herbal remedies *Journal of Medicinal Plants Studies* **7** 179-85
[8] Dike I P, Obembe O O and Adebiyi F E 2012 Ethnobotanical survey for potential anti-malarial plants in south-western Nigeria *Journal of Ethnopharmacology* **144** 618-26
[9] Ene-OjoAtawodi S and Onaolapo G S 2010 Comparative in vitro antioxidant potential of different parts of Ipomoea asarifolia, Roemer & Schultes, Guiera senegalensis, JF Gmel and Anisopus mannii NE Brown *Brazilian Journal of Pharmaceutical Sciences* **46** 245-50
[10] Abubakar M, Sule M, Pateh U, Abdurahman E, Haruna A and Jahun B 2000 In vitro snake venom detoxifying action of the leaf extract of Guiera senegalensis *Journal of ethnopharmacology* **69** 253-7
[11] Idu M 2012 [1] ANTIMICROBIAL ACTIVITY AND PHYTOCHEMISTRY OF KHAYA SENEGALENSIS ROOTS *International Journal of Ayurvedic and Herbal Medicine* **2**

[12] Xie W and Du L 2011 Diabetes is an inflammatory disease: evidence from traditional Chinese medicines *Diabetes, Obesity and Metabolism* **13** 289-301
[13] Mohammed S 2013 Quantitative phytochemical and elemental analysis of Guiera senegalensis leaf extract *Journal of Pharmacognosy and Phytotherapy* **5** 204-7
[14] Salehi B, Kumar N V A, Şener B, Sharifi-Rad M, Kılıç M, Mahady G B, Vlaisavljevic S, Iriti M, Kobarfard F and Setzer W N 2018 Medicinal plants used in the treatment of human immunodeficiency virus *International journal of molecular sciences* **19** 1459
[15] Hauwa'u Yakubu Bako M I and Ja'afaru Sani Mohammad M Z 2014 Toxicity studies of aqueous, methanolic and hexane leaf extracts of Guiera senegalensis in rats
[16] Baggio L L and Drucker D J 2007 Biology of incretins: GLP-1 and GIP *Gastroenterology* **132** 2131-57