Comparative Phytochemical Analysis and Antiradical Activity of Five Plants Used for the Treatment of Type 2 Diabetes in Benin

S. Seton a, O. Koukouia*, Y. Koudoro b, J. B. Amagbegnon a, M. Betira a, F. Sonounameto a and C. P. Agbangnan b

a Laboratory of Animal Physiology, Cellular Signalisation and Pharmacology, University of Sciences Technologies, Engineering and Mathematics, Dassa Zoume, Benin.
b Laboratory of Study and Research in Applied Chemistry, Unity of Research and Molecular Interactions (URIM/LERCA/UAC), Cotonou, Benin.

Authors’ contributions

This work was carried out in collaboration among all authors. Authors OK, SS, YK and CPA designed the study. Authors SS and YK wrote the protocol, and wrote the first draft of the manuscript. Authors OK, SS, YK and CPA managed the analyses of the study. Authors SS, JBA, MB and FS managed the literature search. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JPRI/2022/v34i48A36415

Open Peer Review History:

This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/91122

Original Research Article

ABSTRACT

Background: Diabetes remains a real public health problem in the world today. Although considered a disease of rich countries, today diabetes is increasingly a major concern in developing countries and particularly in sub-Saharan Africa. In Benin, its prevalence in 2015 was 12.4%.

Objective: This work aimed to compare the secondary metabolites, the content of phenolic compounds (total phenol, flavonoid) and the antiradical power of five plants (Bambusa vulgaris Schrad. Ex Wendel; Parkia biglobosa (Jacq.) R. Br. Ex G. Don; Mangifera indica L.; Saccharum officinarum L.; and Annona muricata L.) used in Benin by traditional healers to treat type 2 diabetes.

Materials and Methods: Secondary metabolites were identified by coloration and precipitation reactions specific to each family of metabolites. Total phenols were determined by Folin Ciocalteu method. The aluminum trichloride method has been used to quantify total flavonoids. The antiradical capacity was evaluated by 2,2-diphenyl-1-picrylhydrazyl (DPPH).

Results: Plants which leaves were higher in total phenols were Mangifera indica, Parkia biglobosa
and Bambusa vulgaris while Annona muricata and Parkia biglobosa were the richest plants in flavonoids. The hydroethanolic extract of leaves of Bambusa vulgaris (IC$_{50}$=0.28mg/mL), Parkia biglobosa (IC$_{50}$=0.3mg/mL) and Mangifera indica (IC$_{50}$=2.5mg/mL) showed more pronounced antiradical activity than vitamin C (IC$_{50}$=3.2 mg/mL) which were synthetic antioxidant.

**Conclusion:** Our results showed that among the five plants studied Mangifera indica, Parkia biglobosa and Bambusa vulgaris were the richest in total phenols and also those whose leaf extracts had the highest antiradical activities. These three plants could therefore be considered as potential remedies for type 2 diabetes and its complications.

**Keywords:** Antiradical activity; diabetes; medicinal plants; phenolic compounds.

**1. INTRODUCTION**

Diabetes is a global public health problem [1]. Over 422 million adults were living with diabetes in 2014 [2]. In 2012, 1.5 million deaths worldwide were directly attributable to diabetes, the eighth leading cause of death in humans [3]. More than 80% of diabetes deaths occur in low-income countries.[1] The number of diabetics in sub-Saharan Africa were estimated at 19.8 million in 2013 [4]. Diabetes is on the rise in Benin and its prevalence increased from 2.9% in 2008 to 12.4% in 2015 and generated a mortality rate of 2% [5]. Type 2 diabetes and its associated complications are accompanied by oxidative stress, production of free radicals and reactive oxygen species. The chronicity of hyperglycaemia characteristic of type 2 diabetes generates oxidative stress responsible for increased glycolysis which, by increasing mitochondrial membrane potential, increases the production of radicals and inhibits gyceraldehyde-3-phosphate dehydrogenase [6-7]. Oral antidiabetics lead to the normalization of blood sugar only in less than 50% of cases. They have no regressive effect on established lesions and they are contraindicated in renal and hepatocellular insufficiencies [8]. In addition, there are the problems of intolerance, side effects, hypersensitivity and resistance related to antidiabetic drugs [9]. Moreover, in developing African countries and particularly in Benin, the medical care of diabetes is limited by the inaccessibility of certain populations to health centers and the high cost of conventional medicine drugs. In these conditions, populations often resort to medicinal plants for treatment. The Beninese flora is rich and diversified in plants used to treat type 2 diabetes [10]. Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata are some of the plants that are used to treat type 2 diabetes in Benin. It therefore seems essential to direct scientific studies on these plants, which are in high demand in traditional medicine to treat diabetes. It was in this sense that this work compared the quantity of phenolic compounds and the antiradical activity of these five plants.

**2. MATERIALS AND METHODS**

**2.1 Material**

The plant material consisted of the leaves of Bambusa vulgaris Schrad. Ex Wendel POACEAE; Parkia biglobosa (Jacq.) R. Br. Ex G. Don. FABACEAE ; Mangifera indica L. ANACARDIACEAE; Saccharum officinarum L. POACEAE; And Annona muricata L. ANNONACEAE, plants selected on the basis of selection criteria resulting from an ethnopharmacological survey carried out in three departments (Oueme, Atlantique, Collines) of Benin among traditional healers [11].

**2.2 Methods**

**2.2.1 Pretreatment of plants**

After harvesting, five batches of the leaves of the five plants were dried at laboratory temperature until their plant mass stabilized and then reduced to powder.

**2.2.2 Plant extraction**

The extraction was made with hydroethanolic. 5g of powdered biomass were mixed with 100 mL solvent for 72 hours. Further, all the extracts were filtered through Whatman No.1 filter paper and concentrated. The residues were dried to constant weight and stored in the darkness at 4°C to avoid the degradations until use.

**2.2.3 Preliminary phytochemical screening**

Secondary metabolites were carried out by coloration and precipitation reactions specific to each family (Table1: Methods for the identification of secondary metabolites of plants) [12-13].
2.2.4 Determination of phenolic compounds

Total phenol content: Total phenolic content was determined using the Folin-Ciocalteu colorimetric method. This method consisted of using a mixture of phosphotungstic and phosphomolybdic acids, which were reduced during the oxidation of phenols into a mixture of tungsten blue oxide and molybdenum. Finally, the absorbance was measured at 765 nm using a spectrophotometer and the total phenol content was expressed in micrograms of gallic acid equivalence per milligram of dry matter (μg GAE/gEx) [14-15].

Total flavonoids content: The method of aluminum trichloride (AlCl₃) was used to quantify the total flavonoids. This technique was based on the formation of the aluminum complex flavonoids. The absorbance was read at 415 nm using a spectrophotometer and the Total flavonoid content are expressed in micrograms of gallic acid equivalence per milligram of dry matter (μg GAE/gEx) [16].

2.2.5 Evaluation of antiradical activity

The antiradical activity was evaluated by the DPPH method. The principle of this method was based on measuring the trapping free radicals in a solution of DPPH. This trapping was indicated by the disappearance of the purple color of DPPH. The mixture of DPPH solution and the sample was left in the darkness for an hour and the absorbance measured at 517 nm. [17-18]. The trapping percentage was determined by the formula: 

\[ \text{P} = \left( \frac{(\text{Ab W} - \text{Ab S})}{\text{Ab W}} \right) \times 100 \]

P: percentage of trapping; Ab W: absorbance of the white; Ab S: Absorbance of the sample

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Secondary metabolites identified

Table 2 showed the secondary metabolites of five plants (Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata). The five plants contained tannins, alkaloids, sterols and terpenes. Among the five plants studied, only Annona muricata does not contain saponosides and anthocyanins, while mucilages were absent only in Parkia biglobosa. On the other hand, coumarins and reducing compounds were identified only in Annona muricata. Flavonoids were present in the leaves of Bambusa vulgaris, Parkia biglobosa and Saccharum officinarum while leuco-anthocyanins had been reported only in the leaves of Parkia biglobosa, Mangifera indica and Annona muricata.

3.1.2 Phenolic compound content

The calibration curves for determining the contents of total phenols and total flavonoids were shown in Figure 1. The calibration curves for measuring the total phenols content was obtained with the equation \( y = 0.0252x + 0.0189 \) with the coefficient of determination of \( R^2 = 0.98 \). The calibration curves for determining the content of total flavonoids was \( y = 0.1099x + 0.0136 \) with the coefficient of determination \( R^2 = 0.99 \).

Total phenols: The total phenol contents of leaves of Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata were shown in figure 2. The highest content is obtained at the level of Mangifera indica (29.409 mg GAE/gEx) accompanied by that of Parkia biglobosa (26.909 mg GAE/gEx) of the Bambusa vulgaris content (23.298 mg GAE/gEx). The lowest total phenol content was noted in the hydroethanolic extract of Saccharum officinarum (10.639 mg GAE/gEx) and Annona muricata (17.504 mg GAE/gEx).

Total flavonoids: Fig. 3 indicates the flavonoid contents of the hydroethanolic extract of leaves of Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata. The total flavonoid content of the hydroethanolic extract of Annona muricata leaves was 16.892 µg QE/gEx while that of Parkia biglobosa was 6.437 µg QE/gEx. The flavonoid contents of Mangifera indica, Saccharum officinarum and Bambusa vulgaris were respectively 2.915 µg QE/gEx, 2.169 µg QE/gEx and 2.551 µg QE/gEx.

3.1.3 Anti-radical activity of plant extracts

The curves in Figure 4 showed the change in trapping percentage as a function of the concentrations of the hydroethanolic plant extract. At the level of the five curves, there was a gradual increase in trapping percentage with the increase in the concentration of the hydroethanolic extract of leaves of Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata. The concentrations (IC₅₀) of the hydroethanolic extract trapping 50% of the DPPH radical were determined. The IC₅₀ were listed in Table 3.
From the analysis of this table, it appeared that the IC\textsubscript{50} of Bambusa vulgaris, Parkia biglobosa and Mangifera indica were respectively 0.28 mg/mL, 0.3 mg/mL and 2.50 mg/mL. The hydroethanolic extract of Bambusa vulgaris, Parkia biglobosa and Mangifera indica showed a more interesting antiradical activity than vitamin C (IC\textsubscript{50}=3.20 mg/mL) which was a synthetic compound. The IC\textsubscript{50} of the hydroethanolic extract of Annona muricata and Saccharum officinarum were 11.00 mg/mL and 39.00 mg/mL.

### 3.2 Discussion

The leaves of Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata were rich and diversified in secondary metabolites. However, it should be noted that it had been identified in the leaves of Bambusa vulgaris collected in Benin, coumarins and leuco anthocyanins which were absent in our sample [19]. On the other hand, our results were in agreement with those who studied the sample from Ivory Coast [20]. Concerning the leaves of Parkia biglobosa harvested in Nigeria, the absence of the sterols and terpenes were noted whereas that were present in the sample from Benin [21]. The leaves of Annona muricata, contain flavonoids in accordance with other results [22]. Regarding the leaves of Mangifera indica harvested in Mauritius, the presence of flavonoids and coumarins were noted which were absent in that of Benin [23]. The variation in secondary metabolites observed in our samples compared to previous work could be related to the harvest period, the nature of the soil or climatic factors [24]. The diversity in secondary metabolites of these plants could explain their uses in traditional medicine. Some results had shown that tannins, flavonoids, alkaloids, and saponins have antidiabetic activities [25-26].

Our results showed that the leaves of Mangifera indica, Parkia Biglobosa and Bambusa vulgaris were the richest in total phenols while Annona muricata and Saccharum officinarum were the least rich. It was reported that phenolic compounds were useful in the prevention of type 2 diabetes [27-32].

The hydroethanolic extract of the leaves of the five plants (Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata) showed interesting antiradical activities. It should be noted that the hydroethanolic leaf extract of Bambusa vulgaris, Parkia biglobosa and Mangifera indica showed more pronounced antiradical activity than vitamin C, which is a synthetic antioxidant. Our results were consistent with previous work on the antiradical activity of these plants [29-33]. The plants which had the weakest IC\textsubscript{50} and therefore had the highest antioxidant activities are those which contained the significant quantities of total phenols. With the exception of Annona muricata which contains few total phenols but was rich in vitamin C a good antioxidant [34]. The role of polyphenols as an antioxidant was no longer to be demonstrated, [35,36,37,38] so it was consistent that these plants have high antioxidant activities. Oxidative stress had also been shown to induce insulin resistance which leads to type 2 diabetes [39-40]. Hence Bambusa vulgaris, Parkia biglobosa, Mangifera indica and Annona muricata leaves with their high antioxidant activities could prevent insulin resistance and therefore prevent type 2 diabetes and its complications which were also linked to oxidative stress.

| Secondary metabolites               | Chemical test                                      |
|-------------------------------------|---------------------------------------------------|
| Alkaloids                           | Mayer’s test and Drangendorffs test                |
| Anthocyanins                       | test with hydrochloric acid and ammonia           |
| Anthraquinones                     | Bomtranger’s test                                 |
| Coumarins                          | 365 nm fluorescence test                          |
| Flavonoids                         | Shibita’s reaction test                           |
| Tannins                            | stiasny test, ferric chloride and sodium acetate test |
| Saponins                           | Frothing test                                     |
| Leuco anthocyanins                 | Bate-Smith and metcalf                            |
| Mucilage                           | flaky test                                        |
| Cyanogenic derivatives             | picric acid test                                  |
| Reducing compound                  | Fehling’s test                                    |
| Sterols and terpenes               | Liebermann-Burchard’s test                        |
Table 2. Secondary metabolites of plants

| Secondary metabolites | Bv | Pb | Mi | So | Am |
|-----------------------|----|----|----|----|----|
| Tanins                | +  | +  | +  | +  | +  |
| Flavonoids            | +  | -  | +  | -  | -  |
| Anthocyanins          | +  | +  | +  | +  | -  |
| Leuco anthocyanins    | -  | +  | +  | -  | +  |
| Alkaloids             | +  | +  | +  | +  | -  |
| Reducing compound     | -  | -  | -  | -  | +  |
| Mucilages             | +  | +  | +  | +  | +  |
| Saponins              | +  | +  | +  | +  | -  |
| Cyanogenic derivatives| -  | -  | -  | -  | -  |
| Sterols and terpenes  | +  | +  | +  | +  | -  |
| Coumarins             | -  | -  | -  | -  | +  |
| Quinone derivatives   | -  | -  | -  | -  | -  |
| Anthraquinones        | -  | -  | -  | -  | -  |
| Cardiotonic derivatives| - | - | - | - | - |

*Legends: + : Presence; - : Absence; Bv : Bambusa vulgaris; Pb : Parkia biglobosa; Mi : Mangifera indica; So : Saccharum officinarum; Am : Annona muricata*

Table 3. IC$_{50}$ of the hydroethanolic plant extract

| Hydroethanolic extract       | IC50 (mg/mL) |
|------------------------------|--------------|
| Mangifera indica             | 2.50         |
| Parkia biglobosa             | 0.30         |
| Bambusa vulgaris             | 0.28         |
| Annona muricata              | 11.00        |
| Saccharum officinarum        | 39.00        |
| Vitamine C                   | 3.20         |

Fig. 1. Calibration curves for the evaluation of the levels of phenolic compounds
Fig. 2. Total phenol content of hydroethanolic plant extract

Legends: Bv: Bambusa vulgaris; Pb: Parkia biglobosa; Mi: Mangifera indica; So: Saccharum officinarum; Am: Annona muricata

Fig. 3. Total flavonoids content of hydroethanolic plant extract

Legends: Bv: Bambusa vulgaris; Pb: Parkia biglobosa; Mi: Mangifera indica; So: Saccharum officinarum; Am: Annona muricata

Mangifera indica  
Saccharum officinarum
Annona muricata  Parkia viglobosa

Bambusa vulgaris

Fig. 4. DPPH radical scavenging rate as a function of the concentration of the hydroethanolic extract of plants
4. CONCLUSION

Diabetes is emerging acutely as the silent pandemic of sub-Saharan Africa. As part of the development of medicinal plants used for the treatment of Diabetes, we have chosen 5 plants from our ethno pharmacological survey including Bambusa vulgaris, Parkia biglobosa, Mangifera indica, Saccharum officinarum and Annona muricata. Phytochemical screening revealed the presence of tannins, alkaloids, anthocyanins, flavonoids, mucilages, sterols and terpenes in the plant leaves. Quantitative analysis and antiradical study revealed that among the five plants studied Mangifera indica, Parkia biglobosa and Bambusa vulgaris were the richest in total phenols and also those whose leaf extracts had the highest antiradical activities. These three plants could therefore be considered as potential remedies for type 2 diabetes and its complications.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

ACKNOWLEDGEMENT

All participants in this work are authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Fédération Internationale du Diabète (FID/IDF). ATLAS du diabète 8e édition; 2017. Available: www.idf.org/sites/default/files/EN_6E_Atlas_Full_0.pdf.pdf
2. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. Lancet 2016; published online April 7. Available: http://dx.doi.org/10.1016/S0140-6736(16)00618-8
3. Organisation Mondiale de la Santé (OMS). Rapport mondial sur le diabète. 2016; 88.
4. Houngla MFN. Dietary practices and management of diabetes in diabetics followed at the National Hospital and University Center and at the Insulin Bank of Cotonou in Benin. Dissertation presented to the Faculty of Medicine with a view to obtaining a master's degree in nutrition. Montreal university. Department of Nutrition Faculty of Medicine; 2020.
5. Benin Ministry of Health. National program for the fight against non-communicable diseases (PNLMNT), final report of the survey for the surveillance of risk factors for non-communicable diseases by the WHO “STEPwise” Approach; 2015.
6. Bonnefont-Rousselot DJL, Beaudex P, Thérou J, Peynet A, Le grand J, Delattre. Diabète sucré, stress oxydant et produits de glycation avancée. Annales Pharmaceutiques Françaises. 2004; 62(3):147-157.
7. Berger MM, Manipulations nutritionnelles du stress oxydant : Etat des connaissances. Nutrition Clinique et Métabolisme. 2006;20(1):48-53.
8. Dagnoko S. Study of leaf quality of Sclerocarya birrea (A. Rich) hoscht. used in the treatment of diabetes. Thesis in Medicine, Pharmacy and Odonto-Stomatoloy. University of Bamako; 2009.
9. Jayakumar G, Ajithabai MD, Sreedevi S, Viswanathan PK, Remeshkumar. Ethnobotanical survey of the plants used in the treatment of diabetes. Indian Journal of Traditional Knowledge. 2010;9(1): 100-104.
10. Fah L, Klotôé JR, Dougnon V, Koudokpon, Fanou VB, Dandjesso C. Ethnobotanical study of plants used in the treatment of diabetes in pregnant women in Cotonou and Abomey-Calavi (Benin). Journal of Animal & Plant Sciences. 2013; 18(1):2647-2658.
11. Seton S, Koukoui O, Ewedje E-EBK, Agbo KM, Betira. M, Amagbegnon JB. Ethnopharmacological study of phytomedicines used by traditional healers for the treatment of diabetes and hypertension in some municipalities of Benin, J. Rech. Sci. Univ. Lomé (Togo). 2021;23(4):273-284.
12. Houghton PJ, Raman A. Laboratory handbook for the fractionation of natural extracts. Chapman and Hall, New York. 1998;5:103-108.
13. Dohou R, Yamni K, Tahrouch S, Hassani L I, Badoc A, Gmira N. Screening
phytochimique d’une endémique iberomarocaine, Thymelaea lythroides. Bulletin-Société de Pharmacie de Bordeaux. 2003;142(1/4): 61-78.

14. Singleton VL, Orthofer R, Lamuela-Raventos RM. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. Methods Enzymol. 1999;299:152-178.

15. Koudoro YA, Daye ER, Dassou HG, Atindehou M, Agbangnan DCP, Alitonou GA. Phytochemical screening, antioxidant capacity, antibacterial and anti-inflammatory activities of ethanolic extract of Cordia senegalensis leaves, a plant used in Benin to treat skin diseases. Chemistry Research Journal. 2021; 6(2):137-146;

16. Djeridane A, Yous M, Nadjiemi B, Boutassouna D, Stocker P, Vidal N. Antioxidant activity of some Algerian medicinal plants extracts containing phenolic compounds. Food Chem. 2006; 97:654-660.

17. Brand-Williams W., Cuvelier M.E., Beret C. “Use of a free radical method to evaluate antioxidant activity, Lebensm. Wiss. U. Technol. 1995;28:25-30;

18. Koudoro YA, Mahudro Y, Yehouenou B, Agbangnan DCP, Tchobo FP, Alitonou GA, et al. Chemical study, antiradical and antibacterial potential of the extracts of Ximenia americana and Cussonia arborea of Benin. World Journal of Pharmaceutical Sciences ; 2014. ISSN (Print): 2321-3310; ISSN (Online): 2321-3086.

19. Hessavi BFM., Arlette A, Aimé A, Micheline A, Djikpo T. Investigation ethnobotanique, profil phytochimique et cytotoxicité de Bambusa vulgaris Schrad. Ex J.C. Wendl. (Poaceae), une espèce à usages multiples et sous-utilisée au Bénin. Journal of Animal & Plant Sciences. 2019; 39(2):6435-6453;

20. Appy SA, Kouao AA, Kacou MJ D and Kesse PN. Phytochemical and acute toxicity study of aqueous extract of Bambusa vulgaris leaves on Wistar rats. African Journal of Biological Sciences. 2020;107-114.

21. Osuala FN, Kehinde SF and Philippe PEM. Pharmacognostic and antidyseterent screening of mixed ethanol leaf extract of Parkia biglobosa and Acanthus montanus (50:50). Magna Scientia Advanced Research and Reviews. 2021;03(02):017–039;

22. Yang C, Gundala SR, Mukkavilli R, Vangala S, Reid MD, Aneja R. Synergistic interactions among flavonoids and acetogenins in graviola (Annona muricata) leaves confer protection against prostate cancer. Carcinogenesis. 2015;36(6):656-665;

23. Jhaumeer SL, Bhowon MG, Soyfoo S, and Chua LS. Nutritional and biological evaluation of leaves of Mangifera indica from mauritius. Journal of Chemistry. 2018;Article ID 6869294:9 Available:https://doi.org/10.1155/2018/6869294

24. Daddona PE, wright JL, Hutchinson CR. Alkaloid catabolism and mobilization in Catharanthusroseus. Phytochem. 1976; 15:941-945 ;

25. Manolaraki F. Anthelmintic properties of sainfoin (Onobrychis vicifoliiæ): Analysis of the variation factors and the role of the phenolic compounds involved. Doctoral thesis from the University of Toulouse III; 2011.

26. Owolabi OJ, Ayinde BA, Iwogbu ZA, Ogbonna OO. Properties evaluation of the ethanol extract of Musanga cecropioides. Methods and findings in experimental and clinical pharmacology. 2010;32(6):407-411.

27. Mangano S, Williamson G. Polyphenols and phenolic acid from decrease glucose uptake and transport by human intestinal caco-2 cells. Molecular nutrition and food research, 2010;54(12): 1773-1780.

28. Cano-Marquina A, Tarim JJ, Cano A. The impact of coffee on health. Pub Med. 2013;75(1):7-21.

29. Aouissa Itiann, Wen Rehaba. Etude des activités biologiques et de la Toxicité aiguë de l’extrait aqueux des Feuilles de mangifera indica. (anacardiaceae). Universite de Bamako, Faculté de Médecine de Pharmacie et d’Odonto-Stomatologie; 2002.

30. Nawwar M, Ayoub N, Hussein S, Hashim A, Al-Sharawy R, Wende K, Harms M, Lindequist U. Flavonol triglycoside and investigation of the antioxidant and cell stimulating activities of Annona muricata linn. Arch Pharm Res. 2012;35:761-767.

31. Millogo-Kone H, Guissou IP, Nacoulma O, Traore AS. Comparative study of leaf and stem bark extracts of Parkia biglobosa against enterobacteria, African Journal of
32. Kaou SF. Etude de la phytochimie et des activités biologiques de *Musa acuminata* L., de *Mangifera indica* L., de *Boerhavia erecta* L. et de *Eclipta prostrata* L. rapport de mémoire de thèse; 2012.

33. Akibou OML, Pascal ADC, Annick BH, Paul Y, Félicien A, And. Dominique KCS. Activités antiradicalaires et étude des composés volatils de trois plantes de la médecine traditionnelle du Bénin : Anchomanes difformis, Parkia biglobosa et Polyalthia longifolia, Journal of Innovation and Applied Studies. 2014;9(4): 1609-1619.

34. Betira Mansouratou, Koukoui Omédine*, Houngbemne Alban, Seton Santorin, Amagbegnon Jean-Baptiste, Sonounameto Fidèle and Sezan Alphonse. Combination of the leaves of *Annona muricata*, *Launaea taraxacifolia* and *Tridax procumbens*: An herbal medicine for the prevention and treatment of hypertension, atherosclerosis and cardiovascular diseases. Acta Scientific Pharmaceutical Sciences. 2021; 5(10):2-8.

35. Francesca Santilli., et al. Oxidative stress in chronic vascular disease: From prediction to prevention. Vascular Pharmacology. 2015;(74):23-37.

36. Khurana S, et al. Oxidative stress and cardiovascular health: therapeutic potential of polyphenols”. Canadian Journal of Physiology and Pharmacology. 2013; 91:198-212.

37. Marta Guasch-Ferré, Jordi Merino, Qi Sun, Montse Fitó, Jordi Salas-Salvadó. Dietary Polyphenols, Mediterranean Diet, Prediabetes, and Type 2 Diabetes: A Narrative Review of the Evidence. Oxidative Medicine and Cellular Longevity. 2017;Article ID 6723931:16.

38. Gideon Gatluak Kang, Nidhish Francis, Rodney Hill, Daniel Waters Christopher Blanchard, Abishek Bommanan Santhakumar. Dietary polyphenols and gene expression in molecular pathways associated with type 2 diabetes mellitus: A review. Int. J. Mol. Sci. 2020;21:140.

39. Haber CA, Lam TK, Yu Z, et al. N-acetylcysteine and taurine prevent hyperglycemia-induced insulin resistance in vivo: Possible role of oxidative stress. The American Journal of Physiology Endocrinology and Metabolism. 2003; 285:744-753.

40. Oluwafemi Omoniyi Oguntibeju. Type 2 diabetes mellitus, oxidative stress and inflammation: Examining the links. Int J Physiol Pathophysiol Pharmacol. 2019; 11(3):45-63.

© 2022 Seton et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:
The peer review history for this paper can be accessed here: https://www.sdiarticle5.com/review-history/91122