NJBAS

Available online at http://www.ajol.info/index.php/njbas/index
Nigerian Journal of Basic and Applied Sciences (June, 2023), 31(1): 73-79
DOI: http://dx.doi.org/10.4314/njbas.v31i1.9

ISSN 0794-5698

Full Length Research Article

Effect of *Syzygium guineense* and *Borassus aethiopum* Leaves on Protein Glycation and Oxidative Stress Suppression

***H.S. Usman, R. Musa, M.A. Usman, S.M. Hassan, F.E. Audu and A.B. Sallau**
Department of Biochemistry, Ahmadu Bello University, Zaria, Nigeria
[*Corresponding Author: Email: ummisa71@gmail.com; ☎: +2348069676503]

ABSTRACT
The quest for discovery of a new antiglycation and antioxidant drug still remains a major priority in medicine and related clinical sectors. Against this backdrop, the antioxidant and antiglycation activities of ethylacetate, chloroform, methanol and aqueous extracts of *Syzygium guineense* (SG) and *Borassus aethiopum* (BA) leaves including their phytochemical compositions were evaluated in an *in vitro* trial. DPPH free radical scavenging capacity, antiglycation activity and qualitative phytochemical screening *in vitro* assay were employed respectively. Our result revealed that triterpenes, cardiac glycosides, tannins and flavonoids were detected in the plants leaves extracts. The extracts demonstrated a significantly ($p < 0.05$) low antioxidant and antiglycation activities except the aqueous extract of BA leaves, which displayed a significantly ($p < 0.05$) high antiglycation ability. Overall, data from the current study showed that ethylacetate, chloroform, methanol and aqueous extracts of the plants leaves have potential effect towards lowering oxidative stress and protein glycation and thus should be exploited for further research in the area of drug discovery.
KEYWORDS: *Syzygium guineense*; *Borassus aethiopum*; Antioxidant; Antiglycation; Phytochemicals

INTRODUCTION

Protein glycation and oxidative stress are physiological phenomena associated with a number of human ailments, such as cancer, neurological disorders and cardiovascular diseases (Jha *et al*., 2017; Pizzino *et al*., 2017). Protein glycation is a non-enzymatic reaction between carbonyl groups of reducing sugars and free amino groups of macromolecules like proteins, lipids and nucleic acid (Younus and Anwar, 2016; Froldi *et al*., 2019). This process is a cascade reaction that promotes the generation of reactive oxygen species, auto-oxidation reactions and production of other reactive intermediates (Hellwig and Henle, 2014; Moldogazieva *et al*., 2019). The association between them promotes oxidative damage to DNA, increases inflammatory response and decreases action of the endogenous antioxidant system (Hwang *et al*., 2018; Froldi *et al*., 2019). Unfortunately, the currently available treatment option for protein glycation has been compromised by toxic and severe side effects (Thornalley, 2003). Thus, the need to discover and develop a novel antiglycation agent cannot be overemphasized. Fortunately, there are a number of medicinal plants that have shown therapeutic effects against physiological conditions linked to development of diseases. This could serve as the foundation for isolation of bioactive compounds from plants in order to produce drugs to treat ailments.

Medicinal plants still play an important role in human and animal healthcare. About 60% of the world's population and 80% of Africa's population depend on herbal medicine for their primary healthcare (Opande *et al*., 2022). One of such plants is *Syzygium guineense* (SG), which belongs to the family Myrtaceae. In Africa, the plant is widely distributed in Nigeria, Senegal, Cameroon and South Africa (Nvau *et al*., 2011). Traditionally, the plant parts have beenu sed for the treatment of menstrual cycle disorder (Nigatu, 2004), constipation, diarrhea, dysentery (Kisangau *et al*., 2007), arthritis, rheumatism, venereal diseases, malaria (Kasali *et al*., 2014), sleep disorder, anaemia (Nguyen *et al*., 2016), diabetes mellitus, microbial and fungi infections (Ezenyi *et al*., 2016). Additionally, scientific investigations have demonstrated that the methanol and aqueous extracts of the plant leaves possess antioxidant effect (Pieme *et al*., 2014; Edewor *et al*., 2021). However, the antioxidant activity of the ethylacetate and chloroform extracts of the plant leaves together with the antiglycation potential of these extracts remain a knowledge lacuna that needs to be bridged.

On the other hand, *Borassus aethiopum* (BA) Mart (Arecaceae) is a tropical plant species that grows widely across Africa (Ahmed *et al*., 2010). Studies have indicated that the male inflorescences of the plant exhibited anti-inflammatory, antipyretic, pro-apoptotic, antifungal and antibacterial properties (Sakande *et al*., 2004a, 2004b, 2011, 2012). Nonetheless, the antioxidant and antiglycation activities of extracts of the plant leaves are yet to be assessed in spite of all these preliminary scientific evidences. Herein, we conducted the present study in order to evaluate the *in vitro* antioxidant and antiglycation potentials of SG and BA leaves including their phytochemical constituents.

MATERIALS AND METHODS

Chemicals and Reagents

D-glucose, Bovine serum albumin (BSA), aminoguanidine and sodium azide were obtained from Sigma Aldrich Company, USA. Methanol, ethylacetate, chloroform, ascorbic acid and 1,1- diphenyl-2-picrylhydrazyl (DPPH) were purchased from British Drug House Chemical Limited, Poole, England.

Plant Material

According to literature search, the SG and BA leaves were collected with the help of a traditional healer in May 2018 from local communities in Samaru and Zaria, Nigeria, respectively. The plants were identified at the herbarium unit of the Department of Botany, Ahmadu Bello University, Zaria (ABUZ), Nigeria by matching them to voucher specimen deposited in the unit with the voucher number ABU0186 and ABU016312 for SG and BA leaves, respectively. The leaves of the plants were respectively cleaned, dried in open air in the laboratory for 10 days, pounded into a fine powder with a mortar and pestle and stored in airtight container until further usage.

Preparation of Plant Extract

Two hundred grams (200 g) of the fine powdered plants (SG and BA leaves) were soaked overnight in 500 ml each of ethylacetate, chloroform, methanol and water and filtered through filter paper (Whatman No. 1). The extracts were concentrated at 60°C using a rotary evaporator and dried in a water bath at 45°C. The extracts were stored at 4°C until required.

Percentage Yield

The percentage yield was obtained using dry weight, from the formula below (Adam *et al*., 2019).

%Yield of extract (g/100 g) = (W_1 × 100) / W_2

Where:

W_1 is the weight of the plant extract residue after solvent removal

W_2 is the weight of dried plant powder.

Phytochemical Analysis of Plant Extract

The extracts of SG and BA leaves were subjected to qualitative tests for anthraquinones, steroids, triterpenes, cardiac glycosides, saponins, tannins, flavonoids and alkaloids according to the method described by Evans (2009).

Antioxidant Effect of Plant Extract

The antioxidant power of the extracts, which is the ability of a given substance to scavenge DPPH free radical, was determined using DPPH free radical scavenging assay as described by Sirajuddin *et* al. (2012) and Shah *et al*. (2013). Briefly, 0.1 ml each of methanol, 1 mg/ml ascorbic acid and 1 mg/ml plant extract was added, in triplicate, into control, standard and extract tubes, respectively. Thereafter, 3 ml of 0.24 mg/ml DPPH (prepared in methanol) was added into the test tubes. The mixture was then stirred for 5 min and incubated in the dark at 25°C for 30 min. The absorbance was read at 517 nm. The percentage antioxidant or free radical scavenging activity of the extracts and ascorbic acid was determined using the formula below:

$$Antioxidant\ activity\ (\%) = \frac{Absorbance\ of\ control - Absorbance\ of\ test}{Absorbance\ of\ control} \times 100$$

Antiglycation Effect of Plant Extract

The antiglycation activity of the extracts was estimated based on the method of Matsuura *et al.* (2002) and Kaewnarin *et al*. (2014). In brief, 20 µl each of 800 µg/ml BSA and 200 mM D-glucose were added, in triplicate, into test tubes labeled; standard and plant extracts (ethyl acetate, chloroform and methanol extracts). Following that, 20 µl each of 50 mM phosphate buffer (pH 7.4) containing 0.2 g/l sodium azide was added to testubes labeled standard and the various plant extracts as mentioned above, 1 mg/ml of both aminoguanidine and 1 mg/ml plant extract (prepared in phosphate buffer containing sodium azide) was added into test tubes labeled standard and plant extracts respectively. Afterwards, the mixture was incubated at 37°C for 7 days. The fluorescence intensity was read at an excitation wavelength of 370 nm and an emission wavelength of 440 nm. The percentage antiglycation activity of the extracts and aminoguanidine was calculated using the following below:

Antiglycation activity (%) = (Fluorescence intensity of control-Fluorescence intensity of test)/(Fluorescence intensity of control)×100

Data Analysis

Data were presented as mean ± standard deviation (SD) and analyzed using one way analysis of variance (ANOVA) with the help of Statistical Package for Social Science (SPSS) version 20 for windows. Duncan post-hoc test was conducted to detect differences amongst the mean of the various test solutions. P value less than 0.05 ($p < 0.05$) was considered statistically significant.

RESULTS

The yield of ethylacetate extract of SG leaves was higher (12.05 g) compared to the chloroform, methanol and aqueous extracts. Similarly, the highest yield was obtained when the leaves of BA were extracted with ethylacetate. However, the aqueous extract of SG and BA leaves recorded the lowest yield of 7.5 g and 5.5 g respectively (Table 1).

The phytochemical evaluation of the ethylacetate, chloroform, methanol and aqueous extracts of SG and BA leaves revealed the presence of phytoconstituents like triterpenes, cardiac glycosides, tannins and flavonoids. Furthermore, saponins were identified in all the extracts of the plants leaves with the exception of methanol and aqueous extracts of SG leaves (Table 2).

Table 1: Yield of *Syzygium guineense* and *Borassus aethiopum* leaves extracts

Extract	YIELD (g/100g) *Syzygium guineense*	*Borassus aethiopum*
Ethylacetate	6.025	4.05
Chloroform	4.75	3.65
Methanol	4.2	3.35
Aqueous	3.75	2.75

Table 2: Preliminary phytochemical profile of *Syzygium guineense and Borassus aethiopum* leaf extract

Phytochemicals	PLANT EXTRACTS							
	Syzygium guineense leaves				*Borassus aethiopum* leaves			
	EA	**CHL**	**MEOH**	**AQ**	**EA**	**CHL**	**MEOH**	**AQ**
Anthraquinones	-	-	-	-	-	-	-	-
Steroids	-	-	+	+	+	+	+	+
Triterpenes	+	+	+	+	+	+	+	+
Cardiac glycosides	+	+	+	+	+	+	+	+
Saponins	+	+	-	-	+	+	+	+
Tannins	+	+	+	+	+	+	+	+
Flavonoids	+	+	+	+	+	+	+	+
Alkaloids	-	+	-	+	-	+	-	+

Key: + = detected, - = not detected; EA= ethylacetate; CHL= chloroform; MEOH= methanol; AQ= aqueous

Compared to the ascorbic acid, the antioxidant activity of the ethylacetate and chloroform extracts of SG leaves was significantly (p < 0.05) low. Nonetheless, the ethylacetate extract displayed a higher antioxidant activity (53.67%) compared to the chloroform extract (45.33%) (Figure 1). Similarly, the antioxidant activity of BA leaves extracts was significantly (p < 0.05) low compared to the ascorbic acid. Nevertheless, the chloroform extract recorded the least activity of 3.3% (Figure 2).

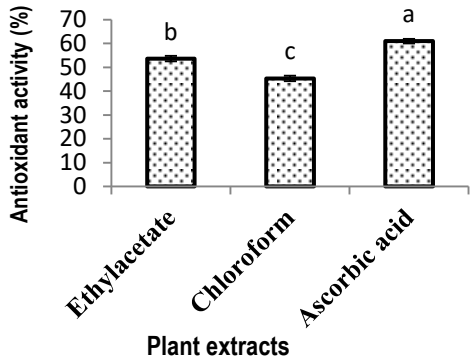

Figure 1: Antioxidant activity of *Syzygium guineense* leaf extract.
Data are presented as the mean ± SD of triplicate values. [a-c]values with different alphabets over the bars are significantly (p < 0.05) different from each other.

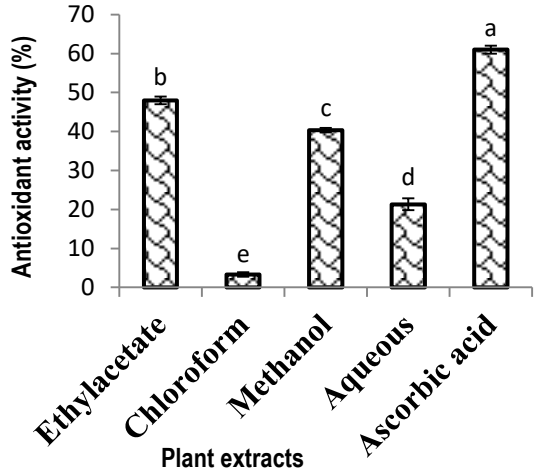

Figure 2: Antioxidant activity of *Borassus aethiopum* leaf extract.
Data are presented as the mean ± SD of triplicate values. [a-e]values with different alphabets over the bars are significantly (p < 0.05) different from each other.

The antiglycation activity of SG leaves extracts was significantly (p < 0.05) low compared to the aminoguanidine. However, the ethylacetate extract had the least antiglycation activity (32.33%) (Figure 3). In addition, the antiglycation activity of the aqueous extract of BA

leaves was significantly ($p < 0.05$) increased compared to the aminoguanidine and other extracts. Nevertheless, the least antiglycation activity was observed with methanol extract of BA leaves (43.33%) (Figure 4).

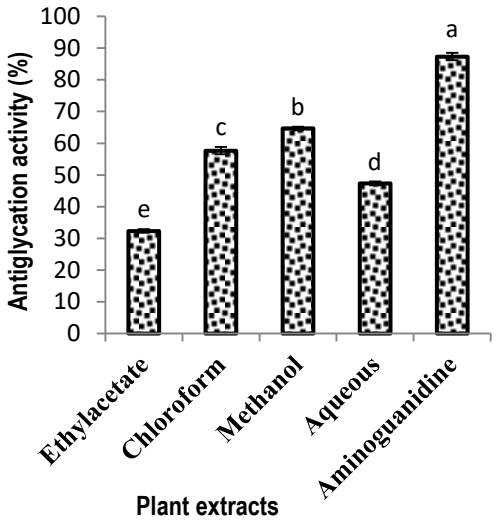

Figure 3: Antiglycation activity of *Syzygium guineense* leaf extract.
Data are presented as the mean ± SD of triplicate values. [a-e]values with different alphabets over the bars are significantly ($p < 0.05$) different from each other.

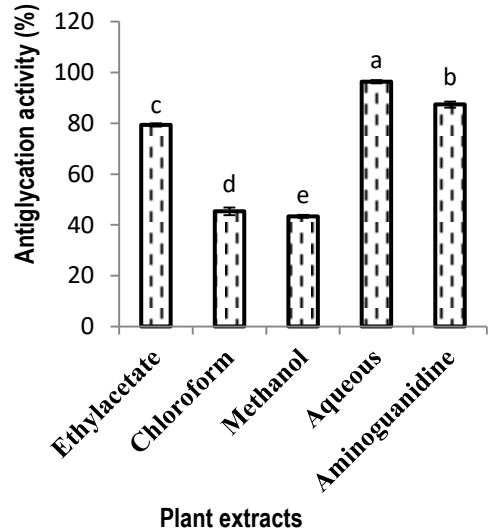

Figure 4: Antiglycation activity of *Borassus aethiopum* leaf extracts.
Data are presented as the mean ± SD of triplicate values. [a-e]values with different alphabets over the bars are significantly ($p < 0.05$) different from each other.

DISCUSSION

The need to discover new therapeutic arsenal towards oxidative stress and protein glycation is on the rise due to the alarming increase in the incidences of diseases associated with these physiological phenomena. Sequel to this, the current study evaluated the phytochemical constituents as well as the *in vitro* antioxidant and antiglycation activities of the ethylacetate, chloroform, methanol and aqueous extracts of SG and BA leaves. The research revealed that the extracts of SG and BA leaves contain vast array of phytochemicals, namely flavonoids, steroids, triterpenes, cardiac glycosides, tannins, saponins and alkaloids. This is supported by previous studies on evaluation of phytoconstituents of plant extracts (Usman *et* al., 2018; Hassan *et al* 2020; Nazneen *et al*., 2016). These phytochemicals have been reported to exhibit potency in some physiological imbalance; for example, flavonoids play a role as antioxidant agents (Savithramma *et al*., 2011); alkaloids are important in antimicrobial, analgesic, and other antispasmodic actions (Savithramma *et al*., 2011; Chatoui *et al*., 2016; El Hattabi *et al*., 2016) also steroids have been found to possess anti-inflammatory potency (Chatoui *et al*., 2016).

To the best of our knowledge, studies on the antioxidant activity of chloroform and ethylacetate extracts of SG are scarce in literature; however, studies on aqueous and methanol extracts of the leaves of SA have been reported previously. Also, there is no existing literature on the antiglycation activity of SG extracts or any existing research on the antioxidant/antiglycation properties of BA leaf extracts. Previous studies have been geared towards determining antioxidant properties of BA fruit flour or fruit extracts (Abe-Inge *et al*., 2018), in lieu of this, the present research was embarked upon.

Our present findings showed that ethyacetate extract of SG and BA gave the highest percentage DPPH radical scavenging capacity *in vitro* (53% and 48% respectively), although this activity was lower compared to the standard (ascorbic acid-61%) used in the study; however, this is in line with the findings of Ibrahim *et al*., (2020) who reported DPPH radical scavenging capacity of *Mangifera indica* ethylacetate leaf extract to be 79%. DPPH scavenging activity of aqueous and ethanol extract of SG stem bark *in vitro* has also been reported previously (Pieme *et al*., 2014; Tankeu *et al*., 2016). Likewise, DPPH scavenging activity of BA flour was reported by previous *in vitro* studies (Amoateng *et al*., 2010). DPPH assay is conventionally considered as an indication of a plant extract's ability to quench free radicals, as well as their hydrogen atom or electron donation ability, in the absence of any enzymatic action (Mileva *et al*. 2014). However, the antioxidant activities exhibited by plant extracts via DPPH scavenging capacity may be due to their hydrogen atom or electron donation ability. The hydrogen-donating ability, on the other hand, may be traceable to the presence of phenolic compounds in the extracts; as these secondary metabolites have been reported to possess antioxidant activities (Gruz *et al*., 2011).

Glycation is a process of non-enzymatic reaction between reducing sugars (fructose or glucose) and amino groups of protein to form a Schiff base complex. The Schiff base formation is not stable; it's rearranged to produce irreversible Amadori products before being involved in further reactions to produce highly reactive carbonyl compounds. The dicarbonyls intermediates can react with amino, sulfhydryl, and guanidine functional groups resulting in browning, denaturation, and cross-linking of the targeted proteins (Frye *et al*., 1998).

Our present findings have reported for the first time the antiglycation activity of BA and SG leaf extracts respectively. This study has shown that aqueous and methanol extract of BA and SG can lower formation of AGEs *in vitro*, with highest antiglycation activity of 96% and 64% for BA and SG respectively. However, BA's ability to inhibit AGE formation was more than that of the standard aminoguanidine (87%). Also, antiglycation activity varied according to the solvent of extraction been used for the experiment (Figures 3 and 4). The observed results for AGEs inhibition by BA and SG are supported by other recent studies (Nampoothiri *et al*., 2011; Tupe *et al*., 2015).

Inhibitors of AGE products may act not only as quenchers of dicarbonyl intermediates, but also as antioxidants or metal ion chelators. Therefore, compounds with antioxidant activity could also inhibit the formation of AGE. Nakagawa *et al*., (2002) reported that green tea demonstrates strong antiglycation activity in addition to its known antioxidant potential. However, Chen *et al*. (2011) describe plant extracts that possess strong antiglycation, but low antioxidant activity (*Astragalus membranaceus*), or strong antioxidant, but low antiglycation potential (*Periploca sepium*). Our research findings thus showed that aqueous extract of BA leaves had a strong antiglycation potential (96%) but possess a lower antioxidant activity (44%) *in vitro*.

CONCLUSION

Our study shows for the first time extracts of *Borassus aethiopum* (BA) and *Syzygium guineense* (SG) leaves possess antiglycation and antioxidant activity *in vitro*. Aqueous extract of BA has the highest inhibitory effect on AGE formation. In order to validate these findings, in vivo research, which is typically the following step in the drug discovery and development pipeline, would be required. Moreover, due to vast array of phytochemicals identified, these plants, might serve potential role as antioxidant and antiglycation agents in modulating the progression of pathogenesis associated with diabetes, cancer, aging and Alzheimers disease.

ACKNOWLEDGEMENT

The management of Ahmadu Bello University, Zaria, Nigeria, provided the study facilities, for which the authors are grateful.

REFERENCES

Abe-Inge, V., Arthur, C., Agbenorhevi, J. K. and Kpodo, F.M. (2018). Mineral Composition, Antioxidant Properties, Phytochemical and Anti-nutrient Composition of African Palmyra Palm (*Borassus aethiopum*) Fruit Flour."*American Journal of Food and Nutrition,* **6(**5): 143-152

Adam, O.A.O., A. Abadi, R.S.M. and Ayoub, S.M.H. (2019). Effect of Extraction method and Solvents on yield and Antioxidant Activity of Certain Sudanese Medicinal Plant Extracts. *The Journal of Phytopharmacology,*.**8**: 248-252.

Ahmed, A., Djibrilla, A., Clerge, T. and Clement, S. D. (2010). Physico-chemical properties of palmyra palm (*Borassus aethiopum* Mart.) fruits from Northern Cameroon. *African Journal of Food Science*, **4**(3): 115-119.

Amoateng, P., Kumah, D. B., Koffuor, G. A. (2010). Antioxidant and Free Radical Scavenging Properties of an Aqueous Ripe Fruit Extract of *Borassus aethiopum*.*West African Journal of Pharmacology and Drug Research*, **26**: 8-14.

Chatoui, K. Talbaoui, A. Aneb, M., Bakri, Y., Harhar, H. and Tabyaoui, M. (2016). Phytochemical screening, antioxidant and antibacterial activity of *Lepidium sativum* seeds from Morocco," *Journal of Materials and Environmental Science*, **7**(8):2938–2946.

Chen, Y.F., Roan, H.Y.; Li, C.K.; Huang, Y.C. and Wang, T.S. (2011). Relationship between antioxidant and antiglycation ability of saponins, polyphenols, and polysaccharides in Chinese herbal medicines used to treat diabetes. *Journal of Medicinal Plants Research*, **5**: 2322–2331.

Edewor, T. I., Akintola, A. O., Ogundola, A. F., Ibikunle, G. J., Adepoju, A. J., Mmuo, A. J. and Owa, S. O. (2021). Phytochemical constituents, total flavonoid and phenolic contents and antioxidant activity of leaves of *Syzygiumguineense. Journal of Pharmacognosy and Phytochemistry*, **10**(4): 127-132.

El Hattabi, L. Talbaoui, A. Amzazi, S., Bakri, Y., Harhar, H., Costa, J. and Tabyaoui, M. (2016). Chemical composition and antibacterial activity of three essential oils from south of Morocco (*Thymus satureoides, Thymus vulgaris* and *Chamaelum nobilis*), *Journal of Materials and Environmental Science*, **7**(9):3110–3117.

Evans, W.F. (2009). Trease and Evans Pharmacognosy 16th Edition. Elsevier Saunders, London:603Pp.

Ezenyi, I. C., Mbamalu, O. N., Balogun, L., Omorogbe, L., Ameh, F. S. and Salawu, O. A. (2016). Antidiabetic potentials of *Syzygium guineense* methanol leaf extract. *Journal of Phytopharmacology*, **5**: 150-156.

Froldi, G., Baronchelli, F., Marin, E. and Grison, M. (2019). Antiglycation activity and HT-29 cellular uptake of Aloe-Emodin, Aloin, and Aloe arborescens leaf extracts. *Molecules*, **24**(11): 2128.

Frye, E. B.,Degenhardt, T. P., Thorpe, S. R. and Baynes, J. W. (1998). Role of the Maillard reaction in aging of tissue proteins: advanced glycation end product-dependent increase in imidazolium cross-links in human lens proteins," *Journal of Biological Chemistry*, **273** (30):18714–18719.

Gruz, J., Ayaz, F.A., Torun, H. and Strnad, M. (2011). Phenolic acid content and radical scavenging activity of extracts from medlar (*Mespilus germanica* L.) fruit at different stages of ripening. *Food Chemistry*.**124**(1): 271-277

Hassan, A., Akmal,Z. and Khan, N. (2020) The Phytochemical Screening and Antioxidants Potential of *Schoenoplectus triqueter* L. Palla, *Journal of Chemistry*, **2020**:8.

Hellwig, M. and Henle, T. (2014). Baking, ageing, diabetes: a short history of the Maillard reaction. *Angewandte Chemie International Edition*, **53**(39): 10316-10329.

Hwang, S. H., Kim, H. Y., Zuo, G., Wang, Z., Lee, J. Y. and Lim, S. S. (2018). Anti-glycation, carbonyl trapping and anti-inflammatory activities of chrysin derivatives. *Molecules*, **23(**7): 1752.

Ibrahim, Y.O., Busari, M.B., Yusuf, R.S. and Hamzah, R.U. (2020). In vitro Antioxidant Activities of Ethanol, Ethyl Acetate and n-Hexane Extracts of *Mangifera indica* Leaves. *Tanzania Journal of Science*. **46**(3): 628-635

Jha, N., Ryu, J. J., Choi, E. H. and Kaushik, N. K. (2017).Generation and role of reactive oxygen and nitrogen species induced by plasma, lasers, chemical agents, and other systems in dentistry. *Oxidative Medicine and Cellular Longevity*, 2017.

Kaewnarin, K., Niamsup, H., Shank, L. and Rakariyatham, N. (2014). Antioxidant and antiglycation activities of some edible and medicinal plants. *Chiang Mai Journal of Science*, **41**(1): 105-116.

Kasali, F. M., Mahano, A. O., Kadima, N. J., Mpiana, P. T., Ngbolua, K. N. and Tshibangu, T. S. D. (2014). Ethnopharmacological survey of medicinal plants used against malaria in Butembo City (DR Congo). *Journal of Advanced Botany and Zoology*, **1**(1): 1-11.

Kisangau, D. P., Lyaruu, H. V., Hosea, K. M. and Joseph, C. C. (2007). Use of traditional medicines in the management of HIV/AIDS opportunistic infections in Tanzania: a case in the Bukoba rural district. *Journal of Ethnobiology and Ethnomedicine*, **3**(1): 1-8.

Matsuura, N., Aradate, T., Sasaki, C., Kojima, H., Ohara, M., Hasegawa, J. and Ubukata, M. (2002). Screening system for the Maillard reaction inhibitor from natural product extracts. *Journal of Health Science*, **48**(6): 520-526.

Mileva, M., Kusovski, V.K., Krastev, D.S., Dobreva, A.M. and Galabov, A.S. (2014). Chemical composition, in vitro antiradical and antimicrobial activities of Bulgarian *Rosa alba* L. essential oil against some oral pathogens. *International Journal of Current Microbiology and Applied Sci*ences, **3**(7): 11-20

Moldogazieva, N. T., Mokhosoev, I. M., Mel'nikova, T. I., Porozov, Y. B. and Terentiev, A. A. (2019). Oxidative stress and advanced lipoxidation and glycation end products (ALEs and AGEs) in aging and age-related diseases. *Oxidative Medicine and Cellular Longevity*: 2019.

Nakagawa, T.; Yokozawa, T.; Terasawa, K.; Shu, S.; Juneja, L.R. (2002). Protective activity of green tea against free radical-and glucose-mediated protein damage. *Journal of Agriculture and Food Chemistry*, **50**: 2418–2422.

Nampoothiri, S.V., Prathapan, A., Cherian, O.L., Raghu, K.G., Venugopalan, V.V. and Sundaresan, A. (2011). *In vitro* antioxidant and inhibitory potential of *Terminalia bellirica* and *Emblica officinalis* fruits against ldl oxidation and key enzymes linked to type 2 diabetes. *Food and Chemical Toxicology*, **49**:125–131.

Nazneen, F., Sheikh, M.A., Jameel, A., Rahman, Z. (2016) Phytochemical screening, antiglycation and antioxidant activities of whole plant of *Boerhavia repens* L. from Cholistan, Pakistan. *Pakistan Journal of Pharmaceutical Science,*.**29**(3):1063-70

Nigatu, B. (2004). Anti-spasmodic, anti-diarrheal and LD50 determination of *Syzygium guineese* in animal model. (https://citeseerx.ist.psu.edu/viewdoc/download?).

Nguyen, T. L. Rusten, A. Bugge, M. S. et al., (2016). "Flavonoids, gallotannins and ellagitannins in Syzygium guineense and the traditional use among Malian healers," Journal of Ethnopharmacology, **192**, 450–458.

Nvau, J. B., Oladosu, P. O. and Orishadipe, A. T. (2011). Antimycobacterial evaluation of some medicinal plants used in plateau State of Nigeria for the treatment of tuberculosis. *Agriculture and Biology Journal of North America*, **2**(9): 1270-1272.

Opande, G. T. (2022). Phytochemical Screening and Antimicrobial Properties of *Carissa edulis* Extracts Obtained from Kaimosi Forest, Vihiga County,

Kenya. *European Journal of Medicinal Plants*, **33**(10): 11-18.

Pieme, C. A., Ngoupayo, J., Khou-KouzNkoulou, C. H., MouketteMoukette, B., NjinkioNono, B. L., Ama Moor, V. J. and YonkeuNgogang, J. (2014). *Syzyguim guineense* extracts show antioxidant activities and beneficial activities on oxidative stress induced by ferric chloride in the liver homogenate. *Antioxidants*, **3**(3): 618-635.

Pizzino, G., Irrera, N., Cucinotta, M., Pallio, G., Mannino, F., Arcoraci, V. and Bitto, A. (2017). Oxidative stress: harms and benefits for human health.*Oxidative Medicine and Cellular Longevity*, **2017**, 1-13.

Sakande, J., Nacoulma, O. G., Nikiema, J. B., Lompo, M., Bassene, E. and Guissou, I. P. (2004a). Study of the antipyretic effect of *Borassus aethiopum* male inflorescences extracts. *Medecined Afrique Noire*, **51**: 280-282.

Sakande, J., Nikiéma, A., Kabré, E., Lompo, M., Nikiema, J. B., Nacoulma, O. G. and Guissou, I. P. (2012). *In vitro* assay of potential antifungal and antibacterial activities of extracts of *Borassus aethiopum* Mart. *Biokemistri*, **24**(1): 48-51.

Sakande, J., Nikiema, J. B., Lompo, M., Nacoulma, O. G., Bassene, E. and Guissou, I. P. (2004b). Study of the anti-inflammatory activity of extracts of *Borassus aethiopum* Mart (Arecaceae). *African Journal of Medicine and Pharmacy* **18**: 45-51.

Sakande, J., Rouet-Benzineb, P., Devaud, H., Nikiema, J. B., Lompo, M., Nacoulma, O. G. and Bado, A. (2011). Dichloromethane-methanol extract from *Borassus aethiopumn* Mart. (Arecaceae) induces apoptosis of human colon cancer HT-29 cells. *Pakistan Journal of Biological Sciences,* **14**(10): 578-583.

Savithramma, N., Rao, M. L. and Suhrulatha, D. (2011). Screening of medicinal plants for secondary metabolites, *Middle-East Journal of Scientific Research***, 8** (3):579–584.

Shah, N. A., Khan, M. R., Ahmad, B., Noureen, F., Rashid, U. and Khan, R. A. (2013). Investigation on flavonoid composition and anti-free radical potential of *Sida cordata*. *BMC Complementary and Alternative Medicine*, **13**(1): 1-12.

Sirajuddin, M., Ali S., Shah, N.A., Khan, M.R. and Tahir M.N. (2012). Synthesis, characterization, biological screenings and interaction with calf thymus DNA of a novel Azomethine 3-((3, 5-dimethylphenylimino) methyl) benzene-1, 2-diol. Spectro Acta Part A: *Molecular and Biomolecular Spectroscopy*, **94**:134–142.

Tankeu, F.N., Pieme, C.A., BiapaNya, C.P. Njimou, R.J., Moukette, B.M., Chianese, A. and Ngogang, J.Y. (2016). *In vitro* organo-protective effect of bark extracts from *Syzygium guineense var macrocarpum* against ferric-nitrilotriacetate-induced stress in wistar rats' homogenates. *BMC Complementary Alternative Medicine*,**16**: 315.

Thornalley, P. J. (2003). Use of aminoguanidine (Pimagedine) to prevent the formation of advanced glycation end products. *Archives of Biochemistry and Biophysics*, **419**(1): 31-40.

Tupe, R. S., Sankhe, N.M., Shaikh, S.A., Phatak, D.V., Parikh, J.U., Khaire, A.A. and Kemse, N.G. (2015). Aqueous extract of some indigenous medicinal plants inhibits glycation at multiple stages and protects erythrocytes from oxidative damage-an *in vitro* study. *Journal of Food Science and Technology*, **52**(4):1911-23.

Usman, H.S., Sallau, A.B., Salihu, A. and Nok, A.J. (2018). Larvicidal assessment of fractions of *Aristolochia albida* rhizome on *Culex quinquefasciatus*. *Tropical Journal of Natural Product Research*, **2**(5):227-234.

Younus, H. and Anwar, S. (2016). Prevention of non-enzymatic glycosylation (glycation): Implication in the treatment of diabetic complication. *International Journal of Health Sciences*, **10**(2): 261.