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IN VITRO ANTIOXIDANT POTENTIAL AND INHIBITORY EFFECT OF HYDRO-ETHANOLIC EXTRACT FROM AFRICAN BLACK VELVET TAMARIND (*DIALIUM INDIUM*) PULP ON TYPE 2 DIABETES LINKED ENZYMES

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ABSTRACT

The alarming rate of diabetes mellitus (DM) globally is bothersome and has drawn the search light of researchers on naturally endowed phytonutrients being an alternative in managing the menace. Therefore, the current study was designed to investigate some antioxidant parameters embedded in the extract of *Dialium indium* (*DI*) fruit pulp and also, to elucidate its antidiabetic potentials through the inhibition of two key carbohydrate-metabolizing enzymes such as α-amylase and intestinal α-glucosidase. Hydro-ethanolic extract of *DI* fruit pulp was used for the antioxidants and enzyme inhibitory bioassays through various convectional antioxidant assay methods *in vitro*. In the results, total phenolic content of the extract had; 6.74 ±3.38 mg GAE.g^{-1}, total flavonoid contents; 0.02 ±0.01 mg QE.g^{-1} and FRAP; 0.84 ±0.47 mg AAE.g^{-1} dried sample. Also, there was a marked significant (p <0.05) difference observed in the inhibition of α-amylase and intestinal α-glucosidase by the different concentrations of the extract used in concentration-dependent manner with their different EC_{50}. The inhibition demonstrated against these two carbohydrate metabolizing enzymes possibly could be through the embedded antioxidant potentials of the fruit pulp and this if properly harnessed, it could be helpful in the management of type 2 diabetes.

Keywords: Type 2 Diabetes; α-amylase; *Dialium indium*; α-glucosidase; antioxidant

INTRODUCTION

Type 2 diabetes (T2D) is a common and chronic disorder caused by impaired cellular carbohydrate metabolism characterized by elevated serum glucose level **(Beverley and Eschwège, 2003)**. Pancreatic beta-cell damage has been major cause of this disorder, leading to failure of β-cells to appropriately secrete insulin **(Porte and Kahn, 2001)**. Extremely elevated glucose level, if not treated could induce the mitochondria and non- mitochondria generation of free radicals **(Oyedemi et al., 2017)**, that subsequently could lead to damage by the free radicals in various tissues **(Afolabi et al., 2018a; Nishikawa et al., 2000; Dave and Kalia, 2007)**. The prolonged exposure of pancreatic β-cells to these reactive oxidative species, utters insulin genetic expression and insulin production as a result of little antioxidant enzymes' capacity **(Robertson and Harmon, 2007)**. Other innately to disease factors namely; hyperinsulinemia, insulin resistance, damaged insulin production, declined insulin mediated reducing sugar absorption and metabolism have been evident as the cause of this difference between blood glucose intake and pancreatic insulin production **(Gruenwald et al., 2010)**. However, there are indications that, environmental and lifestyle factors also are of major considerations in the cause of T2D **(Zimmet et al., 2001)**. T2D is more prevalent than type 1 diabetes and rapidly growing globally with accounts for over ninety-five percent of the world diabetic population **(Inga et al., 2008)**. Regulation of postprandial hyperglycemia level is important in delaying or preventing T2D **(Madhusudhan and Kirankumar, 2015)**, however, therapeutic approach is a common strategy for decreasing postprandial hyperglycemia in T2D patients, through which there is inhibition of sugar metabolizing enzymes such as alpha-glucosidase and alpha-1,4-glucan-4-glucanohydrolases in the gastrointestinal tract (GIT) **(Krentz and Bailey, 2005; Shim et al., 2003)**. These inhibitions cause reduction in the carbohydrate digestion process and subsequently lessening the postprandial plasma glucose rise **(Rhabasa-Lhoret and Chiasson, 2004)**. The choice pharmaceuticals

African black velvet tamarind (*Dialium indium*) pulp.

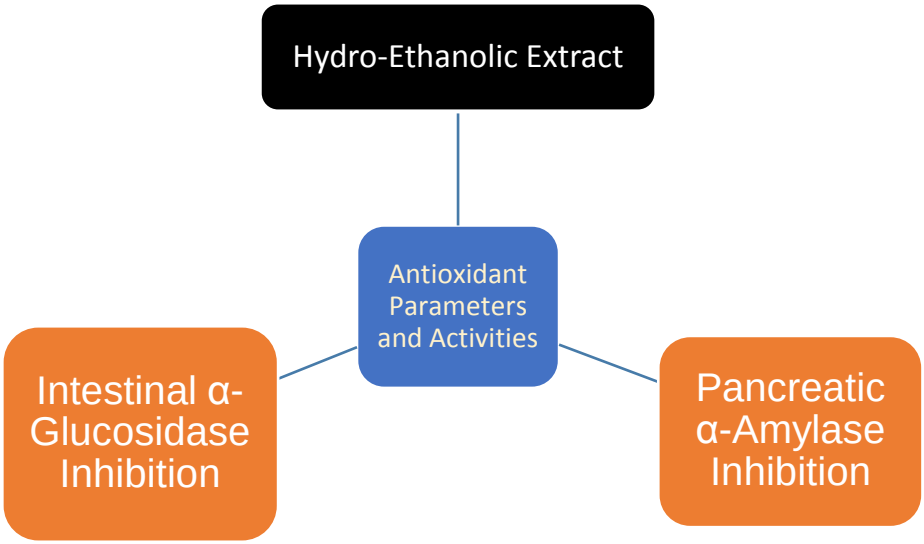


Figure 1 Schematic diagram of the manuscript (Graphical abstract).

in managing diabetes which has taken the highest trend have been reported to have side effects **(Stein et al., 2013; Singh et al., 2007; Hung et al., 2012)**, likely to be low-sugar level, diarrhea, gassiness, and bowel swelling and these have reduced their application in managing T2D. Alpha-amylases and alpha-glucosidases inhibition have been demonstrated by plants' naturally enriched secondary metabolites with promising effects than many commercially available α-glucosidase inhibitors and starch blockers (α-amylase inhibitors) used in the management of T2D **(Jalalpure et al., 2004; Hilary et al., 1998; Erasto et al., 2005)**. These plants are characteristically endowed with polyphenolic compounds, with the ability to interact with proteins, inhibit enzymatic activity, boost the immune system and causes inhibition of pathogenesis in the disease condition and as well has a terminal effect on pathogenic agents **(Afolabi and Oloyede, 2014; McCue et al., 2005; Dawra et al., 1988)**.

Dialium indium (*DI*) commonly known as black velvet tamarind (Figure 2) is among the list of plants that exhibit this natural biological response against infectious and non-infectious diseases. The current work was put together to study *in vitro* the antioxidant potentials, alpha-amylase and alpha-glucosidase inhibitory ability of combined solvent extract (Water: Ethanol, 70:30) of *DI* pulp commonly eaten in Southeastern part of Nigeria **(Nwaukwu and Ikechi, 2012)**.

Scientific hypothesis

If different mg.mL^{-1} of the same extracts is in the future subjected to the same assays as found in the current work, it could be scientifically assumed that same trend would be achieved, only if the same methods and procedures are engaged.

MATERIAL AND METHODOLOGY

Chemicals and Reagents

Chemicals and reagents used such as thiobarbituric acid (TBA), gallic acid, Folin-coicalteau's reagent, intestinal α-glucosidase (EC 3.2.1.20), pancreatic α-amylase (EC 3.2.1.1), *p*-nitrophenyl-α-D-glucopyranose (PNPG), Sodium carbonate, Aluminum chloride ($AlCl_3$), $FeCl_2$ (Iron II chloride), Sodium hydroxide (NaOH) and Potassium ferricyanide were used with 1,1-diphenyl-2-picrylhydrazyl (DPPH), Trichloroacetic acid (TCA) sourced from Sigma-Aldrich, Inc. (St Loius, MO). All these and other chemicals used were of analytical grades and prepared in all-glass apparatus using sterilized distilled water.

Sample collection and preparation

Dialium indium (*DI*) fruits were obtained from a popular place in Ikare Akoko, Ondo State, Nigeria. The voucher sample was dropped at the herbarium of the Department of Plant Science in Ekiti State University, Nigeria. where it was authenticated. Thereafter, the dried sample was blended and kept at moderate temperature.

Figure 2 Different diagrams of African black velvet tamarind (*Dialium indium*).

Preparation of 70% hydro-ethanolic of *DI* pulp

The blended *DI* fruit pulps were air-dried to a constant weight at 37 ±2 °C, about 120 g of the sample was weighed and soaked in 70% ethanol for 72 h. Thereafter, the mixture was processed and the extract concentrated at 50 ^{o}C to dryness.

Antioxidant Content assays

Total phenolic content assay (TPC)

Hydro-ethanolic extract of *DI* pulp was used to determined TPC using the method of **Singleton et al. (1999)**. Appropriate volume of the extract was added to 10% folin-ciocalteau's solution and Sodium carbonate (anhydrous). The mixture was later incubated at 45 °C for 40 min. The absorbance was read at 700 nm.

Total flavonoid content assay (TFC)

Total flavonoid content of hydro-ethanolic of *DI* pulp was determined according to the method of **Bao et al. (2005)**. Appropriate volume of the extract was added to 5% sodium nitrate at zero time. 5 min later, $AlCl_3$ was added and after 6 min, NaOH was added followed by the addition of distilled water. The absorbance of the mixture was taken at 510 nm.

Antioxidant Activity Assays

Ferric reducing antioxidant power (FRAP)

The ferric reducing power of hydro- ethanolic of *DI* pulp was carried out using **Pulido et al. (2000)**. Appropriate volume of the extract was mixed with 200 mM of sodium phosphate buffer (pH 6.6) and 1% potassium ferricyanide. The mixture was incubated at 50 ^{o}C for 20 min, thereafter 250 µL of 10% trichloroacetic acid was added and centrifuged at 2000 rpm for 10 minutes, 250 µL of one percent $FeCl_2$ was added to appropriate volume of the supernatant and the absorbance taken in the spectrophotometer at 700 nm.

1, 1 diphenyl, 2-picrylhyrazine (DPPH) radical scavenging ability assay

Inhibitory effect of hydro- ethanolic extract of *DI* pulp was carried out on DPPH by **Gyamfi et al. (1999)**. The same proportion of the extract and methanolic solution of the DPPH was left in the dark in tubes for 30 min and the absorbance taken in the spectrophotometer at 516 nm.

Hydroxyl radical scavenging assay

Hydro- ethanolic extract of *DI* pulp inhibitory potential against degradation of deoxyribose was determined by method described by **Halliwell and Gutteridge (1981)**. Appropriate dilution of the extract was added to a reaction mixture containing 20 mM deoxyribose, 0.1 M phosphate buffer (pH 7.4), 20 mM hydrogen peroxide and 500 µM $FeSO_4$ and this was made up to 800 µL with distilled water. The reaction was incubated at 37 ^{o}C for a while, and the reaction stopped by the addition of 2.8% trichloroacetic acid, then TBA solution as the colour forming agent. The reaction was boiled for 20 min and the absorbance taken in the spectrophotometer at 532 nm.

Nitric oxide radical scavenging ability

Inhibitory effect of *DI* pulp hydro-ethanolic extract on $NO^{\cdot}$ radical was carried out according to the method of **Mercocci et al. (1994)**. An appropriate volume of the extract was incubated with 25 mM Sodium nitroprusside solution and subsequently incubated for 2 h at room temperature. 500 µL of the incubated mixture was added to 300 µL of Griess solution. The absorbance of the mixture was read in the spectrophotometer at 570 nm and the results expressed as percentage radical scavenging ability.

Enzymes inhibitory Assays

Pancreatic alpha-amylase (EC 3.2.1.1) inhibitory in vitro assay

Inhibitory potential of hydro-ethanolic extract of *DI* pulp against amylase was carried out according to the method of **(Shai et al., 2010)**. Different volumes of the Hydro-alcoholic extract were added to an appropriate volume of the enzyme (2 $U.mL^{-1}$) in 0.1 M Sodium phosphate buffer (pH 6.8) and incubated at 37 °C for 20 min. 1% soluble starch in 0.1 M Sodium phosphate buffer (pH 6.8) was added to the reaction mixture and incubated at 37 °C for 1 h. 1 µL of 3.5 DNSA reagent was added to the reaction mixture boiled for 10 min. The absorbance of the test was taken in the spectrophotometer at 540 nm.

Intestinal alpha-glucosidase (EC 3.2.1.20) inhibitory in vitro assay

Inhibitory potential of hydro-ethanolic extract of *DI* pulp against glucosidase was carried out according to the

method of **Ademiluyi and Oboh (2013)**. Diluted volumes of the extract were added to alpha-glucosidase ($1U.mL^{-1}$) solution in 0.1 M Sodium phosphate buffer (pH 6.8) at 37 °C for 15 min. Thereafter, pNPG solution (0.005 M) in 0.1 M Sodium phosphate buffer (pH 6.8) was added and the mixture was kept at room temperature for 20 min. The absorbance of the *p*-nitro phenol released was measured in the spectrophotometer at 405 nm.

Determination of IC_{50} /EC_{50}.

Determination of IC_{50} / EC_{50} values was carried out from the plot of percentage inhibition caused by the various concentrations of the extract against different concentrations of the extract concentrations. The IC_{50} / EC_{50} was then calculated using a linear regression curve.

Statistical analysis

All experiments were carried out in duplicate. Data were expressed as mean ±standard deviation (SD). Differences were evaluated by one-way analysis of variance (ANOVA) followed by Duncan's multiple test **(Zar, 1984)**. Significance was accepted at *p*-value < 0.05.

RESULTS

Antioxidant Contents

Table 1. Shows the possible antioxidant contents in the hydro-ethanolic extract from *DI* pulp. The total phenolic content revealed significant (p <0.05) in value (mg $GAE.g^{-1}$ of the dried sample) higher than both the total flavonoid (mg $QE.g^{-1}$ of the dried sample).

Antioxidant Activities

Table 1 Shows ferric reducing potential antioxidant activity (mg Ascorbic acid equivalent/g of the dried sample) of the hydro-ethanolic extract from *DI* pulp.

The Figure 3. shows the DPPH inhibitory ability of hydro-ethanolic extract of *DI* pulp in various concentrations. The results indicated significant (p <0.05) difference in the various concentrations considered ranging from 30 – 150 $\mu g.mL^{-1}$ in concentration dependent manner.

The Figure 4shows inhibitory potential of hydro-ethanolic extract of *DI* pulp against deoxyribose degradation in the presence of Fe^{2+}/H_2O_2 and it reveals that, the inhibition was in dose dependent manner with significant (p <0.05) difference.

The Figure 5 shows the inhibitory ability of hydro-ethanolic extract of *DI* pulp against nitric oxide with different concentrations that were varied from 30 – 150 $\mu g.mL^{-1}$. It shows significant (p <0.05) increase in concentration dependent manner with the IC_{50} of the various concentrations shown in Table 2.

Enzymes inhibition

Figure 6 shows pancreatic α- amylase inhibitory potential of hydro-ethanolic extract of *DI* pulp considering various concentrations in $mg.mL^{-1}$. The result revealed significant (p <0.05) difference in the level of inhibition of the extract in concentration dependent manner.

Figure 7 shows the inhibitory potential of hydro-ethanolic extract of *DI* pulp against the activity of intestinal α-glucosidase in various concentrations considered in $mg.mL^{-1}$. The results revealed significant (p <0.05) difference in the level of inhibition of the extract in concentration dependent manner.

DISCUSSION

The timely Monitoring of postprandial long-term blood sugar is so important in the management of diabetes, as all forms of diabetes have very serious implications on human health **(Leszek et al., 2014)**. Recently, inhibitors of

Table 1 The results for total phenolic contents, total flavonoid and ferric reducing property (FRAP) of *DI* pulp hydro-ethanolic extract.

Total Phenolic (mg $GAE.g^{-1}$)	Total Flavonoid content (mg $QE.g^{-1}$)	Ferric reducing power (mg $AAE.g^{-1}$)
6.74 ±3.38	0.02 ±0.01	0.84 ±0.47

The results were expressed as mean values ±SD (n=2).

Table 2 The IC_{50} values in $\mu g.ml^{-1}$ (Concentration of the extracts that will cause 50 percent inhibition) of hydro-ethanolic extract of *DI* pulp were calculated from a linear regression curve of the percentage (%) inhibitions against various concentrations of the extracts.

Inhibitory concentration (IC_{50})	
DPPH Radical Scavenging	179.08 ±1.66
Nitric oxide scavenging ability (%)	96.78 ±0.01
Hydroxyl radical scavenging ability	362.05 ±0.01

Results represent mean values of duplicated sample ±SD, n = 2. Various concentrations were used for the assay to determine the IC_{50}.

Table 3. The EC_{50} values in $\mu g.ml^{-1}$ (Concentration of the extracts that will cause 50 percent inhibition of the enzyme) of hydro- ethanolic extract of *DI* pulp.

Enzyme	α-Amylase	α- glucosidase
EC_{50}	0.52 ±0.06	0.45 ±0.02

The results were expressed as mean values of duplicated sample ±SD, n = 2.

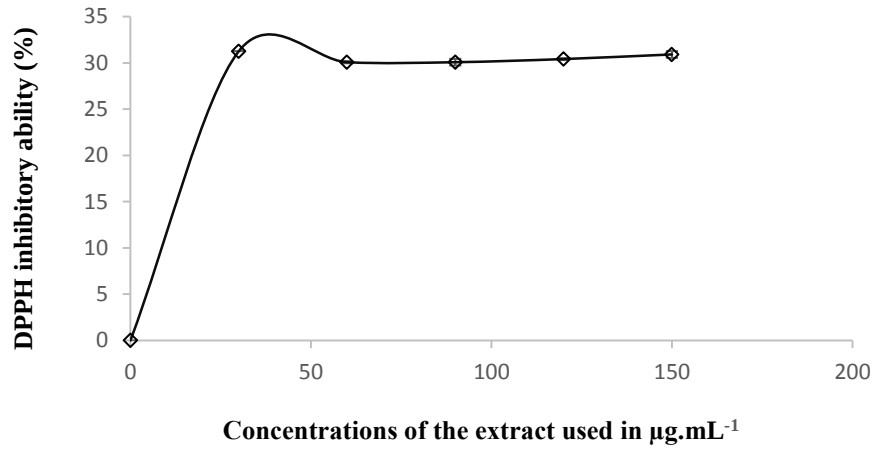


Figure 3 DPPH• radical scavenging ability of hydro-ethanolic extract of *DI* pulp.

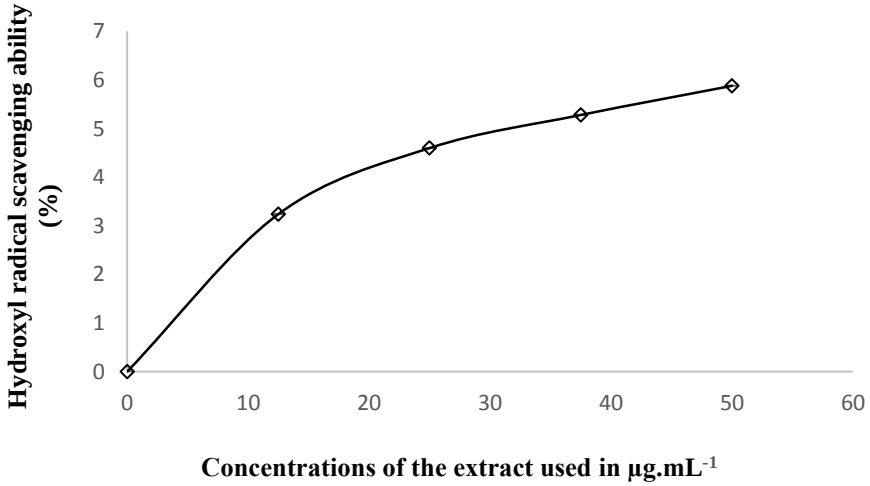
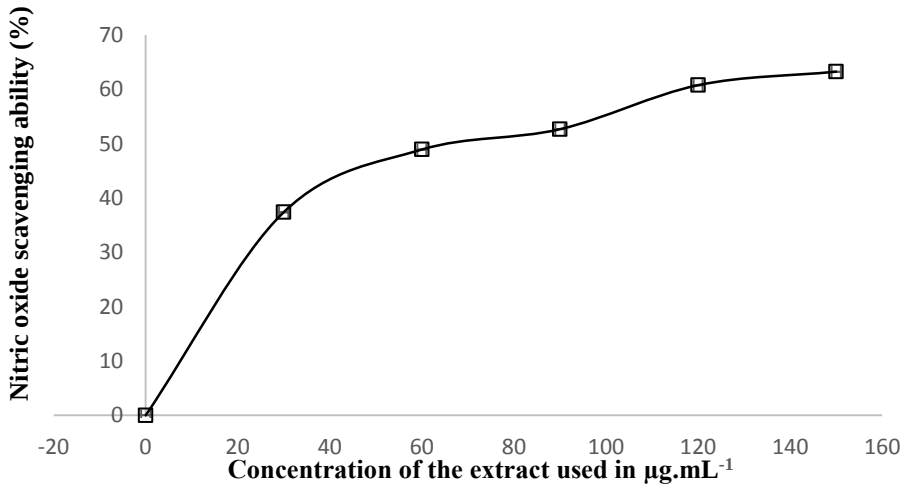


Figure 4 Hydroxyl radical scavenging ability (%) hydro-ethanolic extract of *DI* pulp.



carbohydrate-metabolizing enzymes have been considered to be important in monitoring diabetes mellitus most especially in people living with T2D **(Krentz and Bailey 2005)**. More also, the inhibitory and ameliorating potentials exhibited in the management of diabetes by plants with medicinal values have been credited to the presence naturally endowed polyphenols, which are considered to be potential antioxidants due to the reduction- oxidation properties of their hydroxyl groups **(Afolabi and Oloyede, 2014; Materska and Perucka 2005)**. These plant secondary metabolites fight against generation/proliferation of metabolically induced free radicals which are potential causative agents involve in diabetes. They are readily available in plants in isomeric forms of flavonoids and phenolic acids **(Oberley 1988; Bravo, 1998)**. Most recent studies have implicated flavonoids to have shown inhibition against ROS generation **(Jo et al., 2009)**.

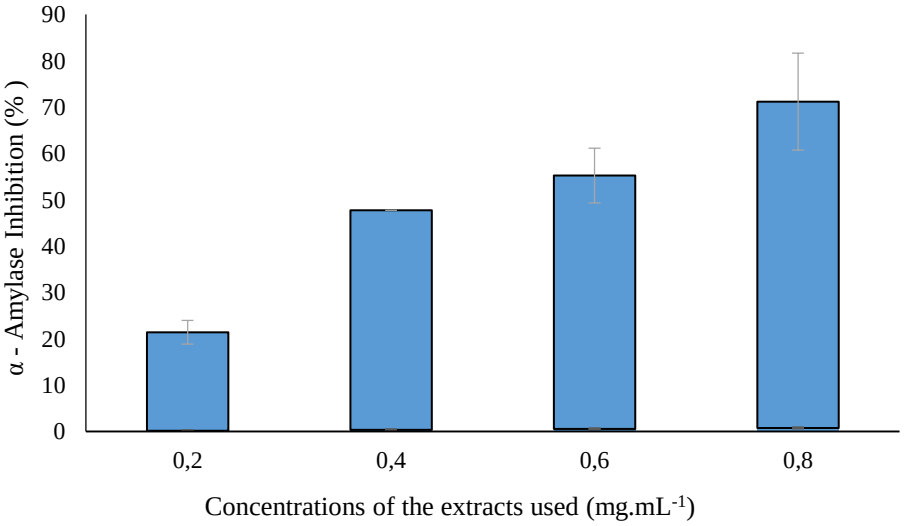


Figure 6 The inhibitory potential of hydro-ethanolic extract of *DI* pulp against the activity of Pancreatic *α*-amylase.

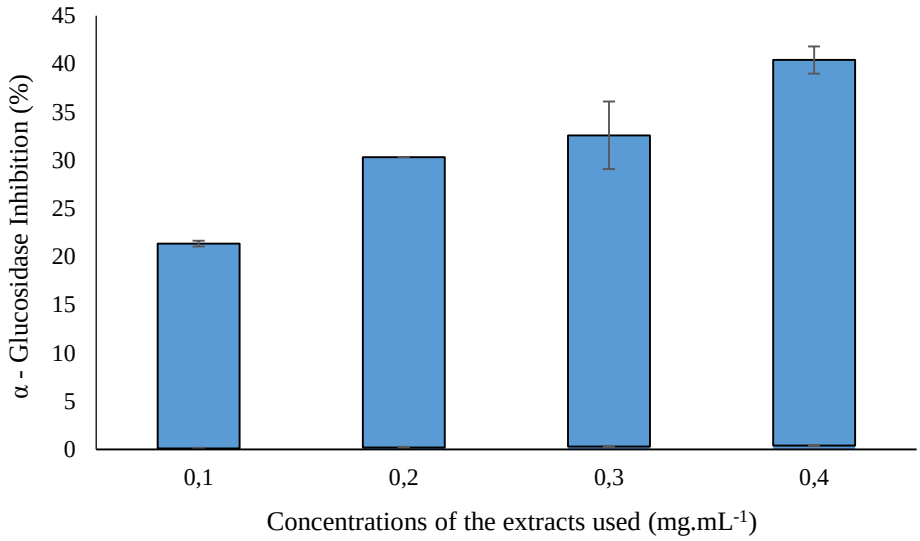


Figure 7 The inhibitory potential of hydro-ethanolic extract of *DI* pulp against the activity of intestinal *α*-glucosidase.

In the current finding, from Table 1, phytonutrients components in the hydro-ethanolic extract of *DI* pulp were revealed, total phenolic content showed predominant value
over total flavonoid and ferric reducing power (FRAP) contents, the reason behind this could not be clearly explained, but it could be attributed to the antioxidant properties embedded in the extract as shown in table 1, however, the finding was in agreement with the result of a **Inglett and Chen (2011)**, that showed high value of phenolic than flavonoid content in the pulp extract of *Synsepalum dulificum* **Ziping et al. (2009)**, their results revealed higher polyphenolic content in the extracts of different *Ziziphus jujube* cultivars. However, in Figure 3 – 5, the ability of the hydro-ethanolic extract of *DI* pulp to inhibit the generation of free radicals were clearly shown. In Figure 3 the antioxidant potential of the extract was demonstrated with the IC_{50} represented in Table 2. Several studies have shown the generation of free radicals to be underlying mechanism of action of some commonly available diabetogenic agents **(Afolabi et al., 2018)**. Antioxidant enriched extracts have been reported to play a pivotal role in the management of Diabetes by scavenging the various ROS generated in the disease. Similarly, as shown from the Figure 4, degradation of deoxyribose inhibitory ability of the hydro-alcoholic extract of *DI* pulp, in the presence of Fe^{2+}/H_2O_2 exhibited percentage inhibitory rise in concentration dependent manner, the mechanism for the inhibiton has not been reported in the current work but, it could be attributed to the antioxidant capacity of the extract as shown in Table 1. In the same vein, Figure 5, reveals the inhibitory potential of *DI* pulp against nitric oxide radical**,** the involvement of $NO^{\bullet}$ radical has been implicated in various diseases through the combination with superoxide radical ($O_2^{\bullet-}$) generated through Fenton reaction that results in the generation of peroxynitrite ($ONOO^-$), a potential cytotoxic molecule, through which oxidation can damage cellular proteins **(Obafemi et al., 2016)**. In the result, all the concentrations of the extract examined caused noticeable changes in the inhibition against the latent production of peroxynitrite. The underlying reason(s) for the several evident inhibitory

potentials of *DI* pulp against oxidant species is/are not known but it could be credited to the presence of quantifiable antioxidant contents present in the hydro-alcoholic extract of *DI* pulp mainly the phenolic acid compound as revealed in Table1.

To fully establish the antidiabetic effects of hydro-ethanolic extract of *DI* pulp, inhibitory potentials of the extract against enzymes involved carbohydrate metabolism were appraised. It has been reported that plants that are rich in secondary metabolites (i. e polyphenols) are potential inhibitors of α-amylases and α-glucosidases **(Afolabi et al., 2018b; Kwon et al., 2007)**. Therefore, pancreatic *α*- amylase and intestinal alpha-glucosidase inhibitions are shown in the Figure 6 and Figure 7 respectively. In the Figures, it was clearly shown that hydro-alcoholic extract of *DI* exhibited inhibitory potentials in all the concentrations examined against these metabolizing enzymes. Apparently, it could be deduced that, the inhibitory potentials shown against this carbohydrate-hydrolyzing enzymes could be attributed to the fact that, the extract exhibited considerable phenolic content, as revealed in the Table 1.

CONCLUSION

In the current study, inhibitory potential on the carbohydrate-hydrolyzing enzymes involved in T2D has apparently been so demonstrated by the hydro-alcoholic extract of DI pulp, this possibly could have been as a result of the embedded antioxidant contents through the free radicals scavenging ability. Howbeit, the possible mechanism (s) of most antidiabetic drugs is/are to target delay in carbohydrate break down process and to cause prolonged overall carbohydrate metabolism time frame, thereby reducing the activities of carbohydrate-metabolizing enzymes and rate of glucose absorption. Thus, the pulp could be suggested helpful as an alternative in the management of T2D when incorporated in diet.

REFERENCES

Ademiluyi, A. Oboh, G. 2013. Soybean phenolic-rich extracts inhibit key-enzymes linked to type 2 diabetes (*α*-amylase and *α* -glucosidase) and hypertension (angiotensin I converting enzyme) *in vitro*. *Experimental and Toxicologic Pathology*, vol. 65, p. 305-309. https://doi.org/10.1016/j.etp.2011.09.005 PMid:22005499

Afolabi O. B, Oloyede O. I, Obajuluwa A. I, Adewale O. B, Olayide I. I, Balogun B. D, Fadugba A. 2018a. Antioxidant properties and inhibitory potentials of different solvent-fractions of *Dialium indium* pulp (African Black velvet tamarind) against Fe^{2+}- induced oxidative stress in rat tissues – *In vitro*. *Potravinarstvo Slovak Journal of Food Sciences*, vol. 12, no. 1, p. 70-78. https://doi.org/10.5219/825

Afolabi, O. B., Oloyede, O. I. 2014. Antioxidant properties of the extracts of *Talinum triangulare* and its Effect on Antioxidant enzymes in tissue homogenate of swiss albino rat. *Toxicology International*, vol. 21, no. 3, p. 307-313. https://doi.org/10.4103/0971-6580.155377 PMid:25948971

Afolabi, O. B., Oloyede, O. I., Olayide, I. I., Obafemi, T. O., Awe, J. O., Afolabi, B. A., Onikani, S. A. 2015. Antioxidant enhancing ability of different solvents extractable components of *Talinum traingulare* in some selected tissue homogenates of albino rat-i*n vitro*. *Journal of Applied Pharmaceutical Science*, vol. 5, no. 9, p. 56-61. https://doi.org/10.7324/JAPS.2015.50911

Afolabi, O. B., Oloyede, O. I., Agunbiade, S. O. 2018b. Inhibitory potentials of phenolic-rich extracts from Bridelia ferruginea on two key carbohydrate-metabolizing enzymes and Fe2+-induced pancreatic oxidative stress. *Journal of Integrative Medicine*, Epub ahead of print.

Bao, J., Cai, Y., Sun, M., Wang, G., Corke, H. 2005. Anthocyanins, flavonols and free radical scavenging activity of Chinese bayberry (*Myrica rubra*) extracts and their color properties and stability. *Journal of Agricultural and Food Chemistry*, vol. 53, no. 6, p. 2327-2332. https://doi.org/10.1021/jf048312z PMid:15769176

Beverley, B., Eschwège, E. 2003. The diagnosis and classification of diabetes and impaired glucose tolerance. In John, C. P. et al. *Textbook of Diabetes*. New Jersey : Wiley-Blackwell, p. 2.1-2.11. ISBN 978-0632059157.

Bravo, L. 1998. Polyphenols: Chemistry, dietary sources, metabolism, and nutritional significance. *Nutrition Reviews*, vol. 56, no. 11, p. 317-333. https://doi.org/10.1111/j.1753-4887.1998.tb01670.x PMid:9838798

Dave, G. S., Kalia, K. 2007. Hyperglycemia induced oxidative stress in type-1 and type-2 diabetic patients with and without nephropathy. *Cellular and Molecular Biology*, vol. 53, no. 5, p. 68-78. PMid:17543235

Dawra, R. K., Makkar, H. P. 1988. Singh B. Protein-binding capacity of micro quantities of tannins. *Analytical Biochemistry*, vol. 170, no. 1, p. 50-53. https://doi.org/10.1016/0003-2697(88)90088-7

Erasto, P., Adebola, P. O., Grierson, D. S., Afolayan, A. J. 2005. An ethnobotanical study of the plants used for the treatment of diabetes in the eastern Cape province, South Africa. *African Journal of Biotechnology*, vol. 4, p. 1458-1460.

Gruenwald, J., Freder, J., Armbruester, N. 2010. Cinnamon and health. *Critical Reviews in Food Science and Nutrition*, vol. 50, no. 9, p. 822-834. https://doi.org/10.1080/10408390902773052 PMid:20924865

Gyamfi, M. A., Yonamine, M., Aniya, Y. 1999. Free radical scavenging action of medicinal herbs from Ghana: *Thonningia sanguinea* on experimentally induced liver injuries. *General Pharmacology*, vol. 32, no. 6, p. 661-667. https://doi.org/10.1016/S0306-3623(98)00238-9

Halliwell, B., Gutteridge, J. M. 1981. Formation of thiobarbituric-acid-reactive substance from deoxyribose in the presence of iron salts: the role of superoxide and hydroxyl radicals. FEBS *Letters*, vol. 128, no. 2, p. 347-352. https://doi.org/10.1016/0014-5793(81)80114-7

Hilary, K., Ronald, E. A., William, H. H. 1998. Global burden of diabetes 1995-2005. Prevalence, numerical estimates and projections. *Diabetes care*, vol. 21, no. 9, p. 141-143.

Hung, H. Y., Qian, K., Morris-Natschke, S. L., Hsu, C. S., Lee, K. H. 2012. Recent discovery of plant-derived anti-diabetic natural products. *Natural Product Reports*, vol. 29, no. 5, p. 580-606. https://doi.org/10.1039/c2np00074a PMid:22491825

Inga, P., Mark, I. M., Cecilia, M. L. 2008. Type 2 diabetes: new genes, new understanding. *Trends in Genetics*, vol. 24, no. 12, p. 613-621. https://doi.org/10.1016/j.tig.2008.09.004 PMid:18952314

Inglett, G. E., Chen, D. 2011. Contents of phenolics and flavonoids and antioxidant activities in skin, pulp, and seeds

of miracle fruit. *Journal of Food Science*, vol. 76, no. 3, p. 479-482. https://doi.org/10.1111/j.1750-3841.2011.02106.x PMid:21535817

Jalapure, S. S., Patil, M. B., Pai, A., Salahuddin, M. D. 2004. Anti-diabetics activity of *Cassia auriculata* seed in alloxan induced diabetes rats. *Nigerian Journal of Natural Products and Medicine*, vol. 8, p. 22-23.

Jo, S. H., Ka, E. H., Lee, H. S., Apostolidis, E., Jang, H. D., Kwon, Y. I. 2009. Comparison of antioxidant potential and rat intestinal α-glucosidases inhibitory activities of quercetin, rutin, and isoquercetin. *International Journal of Applied Research in Natural Products*, vol. 2, p. 52-60.

Krentz, A. J., Bailey, C. J. 2005. Oral antidiabetic agents: Current role in type 2 diabetes mellitus. *Drug*, vol. 65, no. 3, p. 385-411. https://doi.org/10.2165/00003495-200565030-00005

Kwon, Y. I., Apostolidis, E., Kim, Y. C., Shetty, K. 2007. Health benefits of traditional corn, beans and pumpkin: *In vitro* studies for hyperglycemia and hypertension management. *Journal of Medicinal Food*, vol. 10, no. 2, p. 266-275. https://doi.org/10.1089/jmf.2006.234 PMid:17651062

Leszek, C., László, B., Svetlana, B., Agata, B., Jan, B., Katarzyna C, Marek H., Andrej J., Mladen K., Nebojsa L., Emil M., Dario R., Gabriela R., Tsvetalina T., Tamás V., Bogumił W. and Nadia Z. 2014. Self-Monitoring of Blood Glucose in Diabetes: From Evidence to Clinical Reality in Central and Eastern Europe – Recommendations from the International Central-Eastern European Expert Group. *Diabetes Technology and Therapeutics*, vol. 16, no. 7, p. 460-475. https://doi.org/10.1089/dia.2013.0302 PMid:24716890

Madhusudhan, T., Kirankumar, H. 2015. In-vitro α-amylase and α-glucosidase inhibitory activity of *Adiantum caudatum* Linn. and *Celosia argentea* Linn. extracts and fractions. *Indian Journal of Pharmacology*, vol. 47, no. 4, p. 425-429. https://doi.org/10.4103/0253-7613.161270 PMid:26288477

Materska, M., Perucka, I. 2005. Antioxidant activity of the main phenolic compounds isolated from hot pepper fruits (*Capsicum annuum* L.). *Journal of Agricultural and Food Chemistry*, vol. 53, no. 5, p. 1730-1758. https://doi.org/10.1021/jf035331k PMid:15740069

McCue, P., Kwon, Y. I., Shetty, K. 2005. Anti-diabetic and antihypertensive potential of sprouted and solid-state bioprocessed soybean. *Asia Pacific Journal of Clinical Nutrition*, vol. 14, no. 2, p. 145-152. PMid:15927931

Mercocci, L., Marguire, J. J., Droy-Lefaiz, M. T., Parker, L. 1994. The nitric oxide-scavenging properties of *Ginko biloba* extract EGB 761. *Biochemical and Biophysical Research Communications*, vol. 201, no. 2, p. 748-755. https://doi.org/10.1006/bbrc.1994.1764

Nishikawa, T., Edelstein, D., Du, X. L. 2000. Normalizing mitochondrial superoxide production blocks three pathways of hyperglycaemic damage. *Nature*, vol. 404, no. 6779, p. 787-790. https://doi.org/10.1038/35008121 PMid:10783895

Nwaukwu, I. A, Ikechi, N. C. 2012. Biochemical Changes Induced by the Effect of Six Pathogenic Fungi on *Dialium guineense*: Black Velvet Edible Fruit. *IOSR International Journal of Pharmacy and Biological Sciences*, vol. 2, no. 4, p. 20-24. https://doi.org/10.9790/3008-0242024

Obafemi, T. O., Onasanya, A., Olaoye, O. A., Afolabi, O.B., Awe, O. J, Anadozie, S. O., Ojo, O. A., Adedeji, E. 2016. *In vitro* Antioxidant Activity and High Performance Liquid Chromatography (HPLC) Analysis of methanolic extract of *Platycerium angolense. International Journal of Pharmacognosy and Phytochemical Research*, vol. 8, no.9, p. 1497-1502.

Oberley, L. W. 1988. Free radicals and diabetes. *Free Radical Biology and Medicine*, vol. 5, no. 2, p. 113-124. https://doi.org/10.1016/0891-5849(88)90036-6

Oyedemi, S. O., Oyedemi, B. O., Ijeh, I. I., Ohanyerem, P. M. E., Coopoosamy, R. M., Aiyegoro, O. A. 2017. Alpha-amylase inhibition and antioxidative Capacity of some antidiabetic plants used by the traditional healers in southeastern Nigeria. *The Scientific World Journal*, vol. 2017, p. 1-11. https://doi.org/10.1155/2017/3592491 PMid:28367491

Porte, D., Kahn, S. E. 2001. Beta-cell dysfunction and failure in type 2 diabetes: Potential mechanisms. *Diabetes*, vol. 1, p. 160-116. https://doi.org/10.2337/diabetes.50.2007.S160

Pulido, R., Bravo, L., Saura-Calixto, F. 2000. Antioxidant activity of dietary polyphenols as determined by a modified ferric reducing/antioxidant power assay. *Journal of Agricultural and Food Chemistry*, vol. 48, no. 8, p. 3396-3402. https://doi.org/10.1021/jf9913458 PMid:10956123

Rhabasa-Lhoret, R., Chiasson, J. L. 2004. Alpha-glucosidase inhibition. In Defronzo, R. A. et al. *International textbook of diabetes mellitus*. 3rd ed. London, UK : John Wiley, 2070 p. ISBN 9780471486558.

Robertson, R. P., Harmon, J. S. 2007. Pancreatic islet β-cell and oxidative stress: the importance of glutathione peroxidase. *FEBS Letters*, vol. 581, no. 19, p. 3743-3748. https://doi.org/10.1016/j.febslet.2007.03.087 PMid:17433304

Shai, L. J., Masoko, P., Mokgotho, M. P., Magano, S. R., Mogale, A. M., Boaduo, N., Eloff, J. N. 2010. Yeast alpha glucosidase inhibitory and antioxidant activities of six medicinal plants collected in phalaborwa, South Africa. *South African Journal of Botany*, vol. 76, no. 3, p. 465-470. https://doi.org/10.1016/j.sajb.2010.03.002

Shim, Y. J., Doo, H. K., Ahn, S. Y., Kim, Y. S., Seong, J. K., Park, I. S., Min, B. H. 2003. Inhibitory effect of aqueous extract from the gal of *Rhuz chinesis* on alpha-glucosidase activities and postprandial blood glucose. *Journal of Ethnopharmacology*, vol. 85, no. 2-3, p. 283-287. https://doi.org/10.1016/S0378-8741(02)00370-7

Singh, S. K., Rai, P. K., Jaiswal, D., Watal, G. 2007. Evidence-based critical evaluation of glycemic potential of *Cynodon dactylon*. *Evidence-Based Complementary and Alternative Medicine*, vol. 5, no. 4, p. 415-420. https://doi.org/10.1093/ecam/nem044 PMid:18955211

Singleton, V. L., Orthofer, R., Lamuela-Raventos, R. M. 1999. Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. In Packer, L. *Methods in enzymology. Oxidants and antioxidants* Part A. San Diego, California : Academic Press, p.152-178. ISBN 978-12-182200-2.

Stein, S. A., Lamos, E. M., Davis, S. N. 2013. A review of the efficacy and safety of oral antidiabetic drugs. *Expert Opinion on Drug Safety*, vol. 12, no. 2, p. 153-175. https://doi.org/10.1517/14740338.2013.752813 PMid:23241069

Zar, J. H. 1984. *Biostatistical analysis*. 2nd ed. USA : Prentice-Hall Inc, 718p. ISBN 9780130779250.

Zimmet, P., Alberti, K. G., Shaw, J. 2001. Global and societal implications of the diabetesepidemic. *Nature*, vol.

414, no. 6865, p. 782-787. https://doi.org/10.1038/414782a PMid:11742409

Ziping, X., Weihua, F., Jiankang, C., Dongdong, C., Weibo, J. 2009. Antioxidant activity and total phenolic contents in peel and pulp of Chinese *Jujube* (*Ziziphus jujuba* Mill) fruits. *Journal of Food Biochemistry*, vol. 33, no. 5, p. 613-629. https://doi.org/10.1111/j.1745-4514.2009.00241.x

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