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Original Article

In vitro antioxidant activities of African birch (*Anogeissus leiocarpus*) leaf and its effect on the α -amylase and α -glucosidase inhibitory properties of acarbose

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Abstract

Objective

This study sought to determine the [antioxidant activities](#) of African birch leaf, to assess its interaction with key enzymes relevant to [type 2 diabetes](#) (α -amylase and α -glucosidase) and to evaluate its effect on [acarbose](#) *in vitro*.

Methods

One milligram per milliliter of aqueous extract of African birch and acarbose were separately prepared. At the same time, both the African extract and acarbose solution (50:50 v/v) were thoroughly mixed until homogeneity was attained. The phenolic phytoconstituents and antioxidant properties of African birch leaf were subsequently determined. Finally, the effects of African birch extract, acarbose solution and a mixture of acarbose and African birch extract on [\$\alpha\$ -amylase](#) and [\$\alpha\$ -glucosidase](#) activities were assessed *in vitro*.

Results

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The results showed that African birch

exemplified by its radical scavenging abilities, Fe^{2+} chelating ability and prevention of [lipid peroxidation](#). Acarbose had significantly ($p < 0.05$) higher α -amylase ($\text{IC}_{50} = 11.77 \mu\text{g/ml}$) and α -glucosidase ($\text{IC}_{50} = 9.05 \mu\text{g/ml}$) activities compared to African birch extract [α -amylase ($\text{IC}_{50} = 242.17 \mu\text{g/ml}$); α -glucosidase ($\text{IC}_{50} = 196.35 \mu\text{g/ml}$)]. However, the combination of acarbose and African birch extract showed an additive effect on α -amylase inhibition, while a resultant synergistic action was observed against α -glucosidase inhibition.

Conclusion

The additive and synergistic actions of the combination of African birch extract and acarbose solution suggest effective, complementary and alternative strategies towards the management/treatment of [hyperglycaemia](#) associated with type 2 diabetes.

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Keywords

African birch; Acarbose; α -Amylase; α -Glucosidase; Leaf; Type 2 diabetes

Introduction

[Diabetes](#) is a group of metabolic diseases characterized by [hyperglycaemia](#), which results from defects in insulin resistance, [insulin secretion](#) and beta cell dysfunction.¹ Of all of the diagnosed cases of diabetes, NIDDM accounts for approximately 90–95%.² It has been linked to several risk factors involving lifestyle, such as smoking, obesity, poor diet and physical inactivity.³ [\$\alpha\$ -Amylase](#) and [\$\alpha\$ -glucosidase](#) are critical enzymes involved in starch hydrolysis and are implicated in the onset of [type 2 diabetes](#) (T2D).⁴ [Pancreatic \$\alpha\$ -amylase](#) catalyzes the hydrolysis of starch to a mixture of [oligosaccharides](#) and [disaccharides](#), while intestinal α -glucosidase breaks down disaccharides and oligosaccharides into glucose which, upon absorption, enters the bloodstream.⁵ Degradation of these complex carbohydrates is very fast and may result in an elevated blood glucose level after a meal.⁶ Synthetic [oral antidiabetic agents](#) such as [acarbose](#) and [miglitol](#) elicit their therapeutic effects through the inhibition of these enzymes, but their administration is associated with serious side effects and a failure to alleviate diabetic complications.⁷ Recently, interest in the use of medicinal plants in the form of traditional medicine has increased all over the world, especially in Africa, due to their cheap cost, availability and effectiveness.⁸

Nigeria has a wide range of p

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tropical plant with large ecological distribution across Africa. The plant parts (leaf, stem, bark and root) are used in traditional medicine for the treatment of some ailments because they have been reported to possess [antimicrobial](#), hepatoprotective and antioxidant properties.^{10, 11} A previous study by Etuk and Mohammed¹² revealed a spontaneous decrease in blood glucose levels in alloxan-induced diabetic rats administered African birch extract. However, there is a dearth of information on the possible mechanism by which the plant elicits its [antidiabetic effects](#).

Consequently, we aimed to assess the [antioxidant activities](#) and interaction between aqueous African birch leaf extract with key enzymes linked to starch hydrolysis. Additionally, considering the combinatorial usage of traditional plants and synthetic drugs in Nigeria, it is pertinent to evaluate and compare the effects of this plant to acarbose (a known antidiabetic drug) *in vitro*.

Materials and Methods

Materials

Sample collection

African birch leaf was purchased from local traditional healers at the Erekesan Market in Akure Metropolis of Ondo State, Nigeria. Authentication of the plant was performed by the Crop, Soil and Pest Management (CSP) Department at the Federal University of Technology, Akure (FUTA), Nigeria (Voucher specimen no: FUTA/HB/0112AL1).

Chemicals and reagents

All chemicals and reagents used in this study were of analytical grade, and glass-distilled water was used.

Aqueous extraction of African birch leaf and acarbose

African birch leaf was thoroughly washed under running [distilled water](#), air dried, ground into powder and kept dry in an air-tight container prior to extraction according to the method of Adefegha and Oboh.¹³ The sample (5 g) was weighed, soaked in 100 ml of distilled water and left for 24 h. The mixture was filtered after 24 h and the filtrate kept in a refrigerator below 0 °C. The frozen extract solution was recovered as dried extract under pressure of approximately 200–450 mbar at 40 °C. The dried extract was reconstituted in distilled water (1 mg/ml) and used for subsequent analysis. Similarly, a stock concentration of 1 mg/ml [acarbose](#) was prepared and later diluted for subsequent use.

Phenolic characterization

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Determination of total phenolic content

Briefly, 1 mg/ml of extract was oxidized with 2.5 ml of 10% Folin–Ciocalteu's reagent (v/v) and neutralized with 2.0 ml of 7.5% [sodium carbonate](#). The reaction mixture was incubated for 40 min at 45 °C and absorbance was measured at 765 nm using a UV/Visible Spectrophotometer, 6315 Series (Jenway, Chelmsford, Essex CM1 3UP, England). Total phenolic content was subsequently calculated as the [gallic acid](#) equivalent.¹⁴

Determination of total flavonoid content

Briefly, 0.5 ml of extract (1 mg/ml) was mixed with 0.5 ml of methanol, 50 μ l of 10% AlCl_3 , 50 μ l of 1 M [potassium acetate](#) and 1.4 ml of water and incubated at room temperature for 30 min. Absorbance of the reaction mixture was subsequently measured at 415 nm, and total [flavonoid](#) content was calculated and expressed as the [quercetin](#) equivalent.¹⁵

Quantification of phenolic compounds by HPLC-DAD

Reverse phase chromatographic analyses were carried out under gradient conditions using a C_{18} column (4.6 mm \times 150 mm) packed with 5- μ m diameter particles; the [mobile phase](#) was water containing 1% [formic acid](#) (A) and [acetonitrile](#) (B), and the composition gradient was as follows: 13% of B until 10 min and then changed to obtain 20%, 30%, 50%, 60%, 70%, 20% and 10% B at 20, 30, 40, 50, 60, 70 and 80 min, respectively, following the method described by Adefegha et al.,¹⁶ with slight modifications. African birch extract and the mobile phase were filtered through a 0.45- μ m membrane filter (Millipore) and then degassed in an ultrasonic bath prior to use. African birch extract was analyzed at a concentration of 20 mg/ml. The flow rate was 0.7 ml/min, and the injection volume was 40 μ l. The wavelengths were 254 nm for gallic acid; 280 nm for [catechin](#) and [epicatechin](#); 325 nm for chlorogenic, caffeic and [ellagic acids](#); and 365 nm for quercetin, [quercitrin](#), [rutin](#) and [kaempferol](#). All chromatography operations were carried out at ambient temperature and in triplicate.

In vitro antioxidant studies

1,1-Diphenyl-2 picrylhydrazyl free radical scavenging ability

The free radical scavenging ability of the plant extract against [DPPH](#) (1,1-diphenyl-2 picrylhydrazyl) was evaluated as described by Gyamfi et al.¹⁷ Briefly, the extracts (0–500 μ g/ml) were mixed with 1 ml of 0.4 mM methanolic solution containing DPPH radicals. The mixture was left in the dark for 30 min and absorbance was read at 516 nm. DPPH free radical scavenging ability was subsequently calculated and expressed as a percentage (%).

Fenton reaction (degradation of deoxyribose)

The method of Halliwell and

to prevent the $\text{Fe}^{2+}/\text{H}_2\text{O}_2$ -ind [☰ Outline](#) [📄 Download](#) [Share](#) [Export](#)

added to a reaction mixture containing 120 μl of 20 mM acetylacetone, 100 μl of 0.1 M phosphate buffer and 40 μl of 500 μM FeSO_4 , and brought to a final volume of 800 μl with distilled water. The reaction mixture was incubated at 37 °C for 30 min and the reaction stopped by the addition of 0.5 ml of 2.8% [trichloroacetic acid](#). This was followed by the addition of 0.4 ml of 0.6% [thiobarbituric acid](#) solution. The tubes were subsequently incubated in boiling water for 20 min and absorbance was measured at 532 nm. The OH radical scavenging ability was subsequently calculated and expressed as a percentage (%).

Fe^{2+} chelation assay

The Fe^{2+} chelating ability of the extract was determined using a modified method of Minotti and Aust.¹⁹ One hundred fifty microliters of freshly prepared FeSO_4 (500 μM) was added to a reaction mixture containing 168 μl of 0.1 M Tris-HCl (pH 7.4), 218 μl of saline and the extracts (0–200 $\mu\text{g}/\text{ml}$). The reaction mixture was incubated for 5 min before the addition of 13 μl of 0.25% [1,10-phenanthroline](#) (w/v). Absorbance was subsequently measured at 510 nm in a Jenway UV/Visible spectrophotometer, 6315 series. The Fe^{2+} chelating ability was calculated and expressed as a percentage (%).

Lipid peroxidation and thiobarbituric acid reactions

Wistar rats were anaesthetized in mild [diethyl ether](#), and the pancreases were excised. Pancreatic tissue was rapidly rinsed in saline, placed on ice and weighed. The tissue was subsequently homogenized in cold saline (1/10 w/v) with approximately 10 up-and-down strokes in a [Teflon](#) glass homogenizer. The homogenate was centrifuged for 10 min at 3000 \times *g* to yield pellets that were discarded, and low-speed supernatant (S1) was obtained. The lipid peroxidation assay was carried out using the modified method of Ohkawa et al.²⁰ Briefly 100 μl of the S1 fraction was mixed with a reaction mixture containing 30 μl of 0.1 M Tris-HCl buffer (pH 7.4), extracts (0–312.50 $\mu\text{g}/\text{ml}$) and 30 μl of 250 μM freshly prepared FeSO_4 . The volume was brought up to 300 μl with distilled water before incubation at 37 °C for 1 h. The color reaction was developed by adding 300 μl of 8.1% [sodium dodecyl sulfate](#) to the reaction mixture containing S1. This was subsequently followed by the addition of 600 μl acetic acid/HCl (pH 3.4) and 600 μl of 0.8% thiobarbituric acid. This mixture was incubated at 100 °C for 1 h and absorbance was read at 532 nm. [Lipid peroxidation](#) was subsequently calculated as the amount of [malondialdehyde](#) (MDA) produced (% of control).

Enzyme inhibition assay

α -Amylase assay

α -Amylase activity was deterri

birch extract (0–0.8 mg/ml) or  [Outline](#)  [Download](#) [Share](#) [Export](#)

(pH 6.9 with 0.006 M NaCl) containing 100 μ g pancreatic α -amylase (20 U/ml) (0.5 mg/ml) were incubated at 25 °C for 10 min. Then, 50 μ l of 1% starch solution in 0.02 M sodium phosphate buffer (pH 6.9 with 0.006 M NaCl) was added to each tube. The reaction mixtures were incubated at 25 °C for 10 min and stopped with 100 μ l dinitrosalicylic acid color reagent. Thereafter, the mixture was incubated in a boiling water bath for 5 min and cooled to room temperature. The reaction mixture was then diluted by adding 1.0 ml distilled water, and absorbance was measured at 540 nm. α -Amylase inhibitory activity was subsequently calculated and expressed as a percentage (%).

α -Glucosidase inhibition assay

α -Glucosidase activity was determined by the modified method described by Oboh et al.⁴ Fifty microliters of African birch extract (0–0.8 mg/ml) or acarbose (0–80 μ g/ml) and 100 μ l of α -glucosidase solution (1.0 U/ml) in 0.1 M phosphate buffer (pH 6.9) were incubated at 25 °C for 10 min. Then, 50 μ l of 5 mM p-nitrophenyl- α -D-glucopyranoside solution in 0.1 M phosphate buffer (pH 6.9) was added. The mixtures were incubated at 25 °C for 5 min before reading the absorbance at 405 nm. α -Glucosidase inhibitory activity was calculated and expressed as percentage (%) inhibition.

Statistical analysis

The mean values from triplicate experiments were pooled and expressed as the mean \pm standard deviation (STD). One-way analysis of variance was used to analyze the results. Tukey's test was used for the post hoc analysis, and the least significance difference (LSD) was carried out. GraphPad Prism 6 software was used for the analysis. The IC₅₀ (extract concentration causing 50% enzyme inhibitory/antioxidant activity) values were determined using [non-linear regression analysis](#).

Results

Spectrophotometric and HPLC-DAD analysis of phenolics in African birch extract

[Table 1](#) lists the total phenolic contents of African birch leaf. The results show a total phenolic content of 6.87 mg GAE/g and a total [flavonoid](#) content of 4.38 mg QUE/g. Furthermore, HPLC-DAD analysis was performed on African birch leaf extract to identify and quantify the presence of phenolic acids and flavonoids ([Figure 5](#)). The results indicate that the plant extract contains [chlorogenic acid](#) (27.19 ± 0.04 mg/g) and [quercetin](#) (14.69 ± 0.03 mg/g) as the predominant [phenolic compounds](#). Other phenolic compounds found in African birch include [catechin](#) (8.45 ± 0.08 mg/g), [kaempferol](#) (5.72 ± 0.11 mg/g), [rutin](#) (5.43 ± 0.10 mg/g), [epicatechin](#)

(3.17 \pm 0.06 mg/g), [ellagic acid](#)(1.36 \pm 0.04 mg/g) and [caffeic](#) ☰ [Outline](#)[Download](#)[Share](#)[Export](#)Table 1. The total [phenol](#) and [flavonoid](#) content of African birch leaf.

Phenolic contents	African birch
Total phenolic (mg/GAE g)	6.87 \pm 0.45
Total flavonoid (mg/QUE g)	4.38 \pm 0.33

Table 2. Quantification of [phenolic compounds](#) by HPLC-DAD in African birch leaf extract.

Compounds	African birch		LOD	LOQ
	mg/g	%	μ g/mL	μ g/mL
Gallic acid	2.97 \pm 0.07 ^e	0.29	0.019	0.067
Catechin	8.45 \pm 0.08 ^c	0.84	0.024	0.081
Chlorogenic acid	27.19 \pm 0.04 ^a	2.71	0.032	0.039
Caffeic acid	1.14 \pm 0.05 ^g	0.11	0.015	0.049
Ellagic acid	3.08 \pm 0.08 ^e	0.30	0.025	0.083
Epicatechin	3.17 \pm 0.06 ^e	0.31	0.016	0.057
Rutin	5.43 \pm 0.10 ^d	0.54	0.028	0.096
Quercitrin	1.36 \pm 0.04 ^f	0.13	0.013	0.042
Quercetin	14.69 \pm 0.03 ^b	1.46	0.009	0.027
Kaempferol	5.72 \pm 0.11 ^d	0.57	0.034	0.112

Results are expressed as mean \pm standard deviations (SD) of three determinations.

Values with different superscript alphabets (a–g) along the same column are significantly ($p < 0.01$) different using the Tukey test.

Antioxidant properties of

The free radical scavenging a

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Table 3. The results showed that the leaf extract ($IC_{50} = 348.25 \mu\text{g/ml}$) scavenged [DPPH](#).

Additionally, the OH^{\bullet} scavenging ability of the plant sample was determined; the plant extract ($IC_{50} = 183.14 \mu\text{g/ml}$) scavenged OH^{\bullet} . In a similar manner, the plant chelated Fe^{2+} with an IC_{50} value of $187.45 \mu\text{g/ml}$. Incubation of pancreas homogenates in the presence of Fe^{2+} caused a significant increase ($p < 0.05$) in MDA content. However, African birch extract inhibited MDA production with an IC_{50} value of $174.00 \mu\text{g/ml}$, as presented in [Table 3](#).

Table 3. IC_{50} Values for the [DPPH](#) and OH radical scavenging ability, Fe^{2+} chelating ability, inhibition of $FeSO_4$ induced MDA production in rat's pancreas *in vitro*, [\$\alpha\$ -amylase](#) and [\$\alpha\$ -glucosidase](#) inhibitory activities of African birch and [acarbose](#).

Assays	Samples	
	African birch ($\mu\text{g/ml}$)	Acarbose ($\mu\text{g/ml}$)
DPPH \bullet	348.25 ± 3.83	N.D
OH^{\bullet}	183.14 ± 4.16	N.D
Iron chelation	187.45 ± 3.82	N.D
Lipid peroxidation	174.00 ± 2.78	N.D
α -Amylase	$242.17 \pm 4.20^*$	$11.77 \pm 1.25^{**}$
α -Glucosidase	$196.35 \pm 3.30^*$	$9.05 \pm 1.33^{**}$

Values represent means \pm standard deviation of triplicate readings.

Values with asterisk (*) and (**) along the same row are significantly different ($p < 0.05$).

N.D; Not determined.

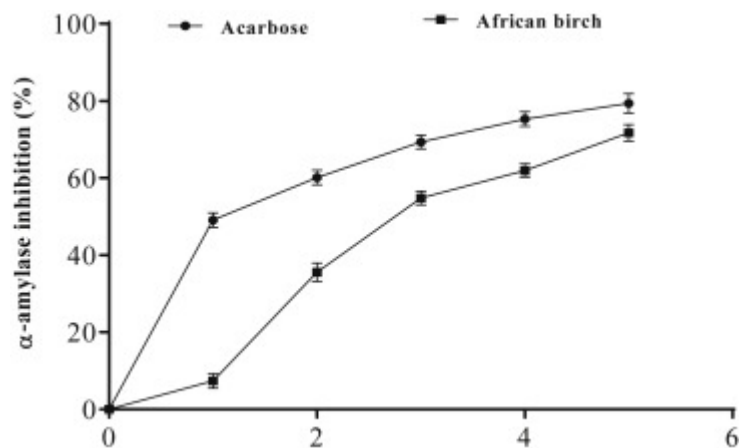
α -Amylase and α -glucosidase inhibitory activities

The [\$\alpha\$ -amylase](#) inhibitory properties of [acarbose](#) and African birch extract were assessed and are presented in [Figure 1](#). The results revealed that both acarbose and the leaf extract inhibited α -amylase activity in a concentration-dependent manner. Acarbose ($IC_{50} = 11.77 \mu\text{g/ml}$) had a significantly ($p < 0.05$) higher α -amylase inhibitory effect than African birch extract ($IC_{50} = 242.17 \mu\text{g/ml}$). The *in vitro* effect of the combination of African birch leaf extract with

acarbose on α -amylase inhibi

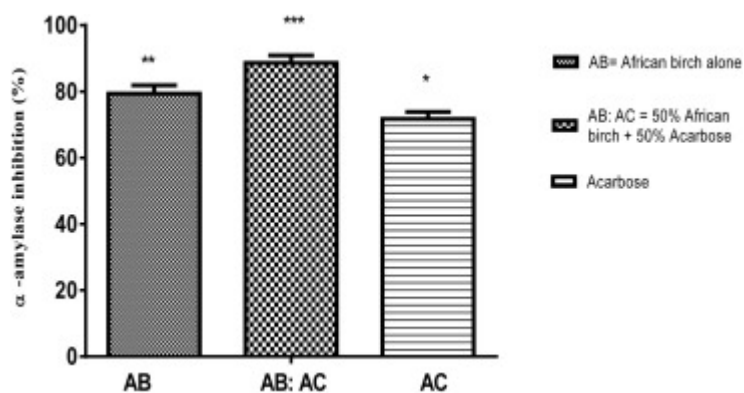
synthetic drug (acarbose) and [Outline](#) [Download](#) [Share](#) [Export](#)

($p < 0.05$) increase in α -amylase inhibitory activity compared with the plant extract only and synthetic drug (acarbose) only. Likewise, the α -glucosidase inhibitory abilities of the plant, acarbose and their combination are presented in [Figure 3](#), [Figure 4](#), and IC_{50} values are listed in [Table 3](#). The results revealed that acarbose ($IC_{50} = 9.05 \mu\text{g/ml}$) had significantly ($p < 0.05$) higher α -glucosidase inhibitory activity than African birch extract ($IC_{50} = 196.35 \mu\text{g/ml}$). Additionally, the combination of African birch extract and acarbose (50:50 v/v) did not cause a significant ($p > 0.05$) change in α -glucosidase inhibitory activity compared with African birch only and acarbose only.



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Figure 1. Inhibition of α -amylase activities (%) by African birch leaf extract and acarbose. The concentrations of the extract used for the plot are 0.00, 0.20, 0.40, 0.6 and 0.80 mg/mL for the values 0, 1, 2, 3 and 4 respectively as indicated on the x-axis of the graph. The concentrations of the acarbose used for the plot are 0.00, 20.00, 40.00, 60.00 and 80.00 $\mu\text{g/mL}$ for the values 0, 1, 2, 3 and 4 as shown on the x-axis of the graph. Values represent mean of standard deviation of triplicate readings.

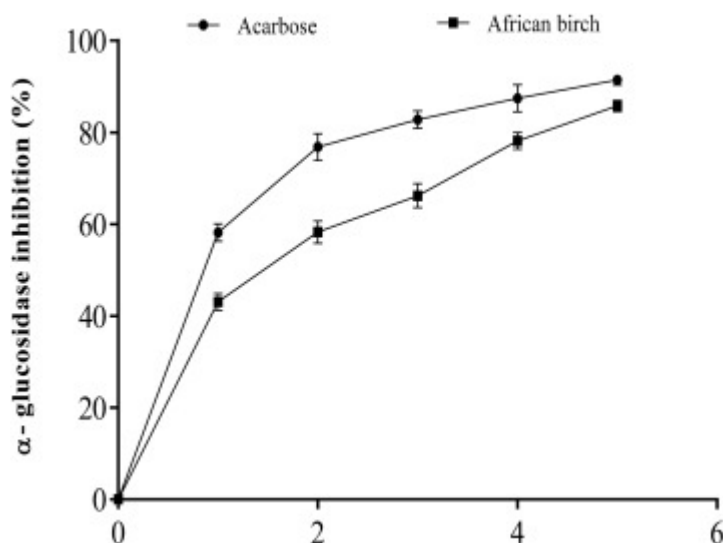


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Figure 2. Inhibition of α -amy [Outline](#) [Download](#) [Share](#) [Export](#)

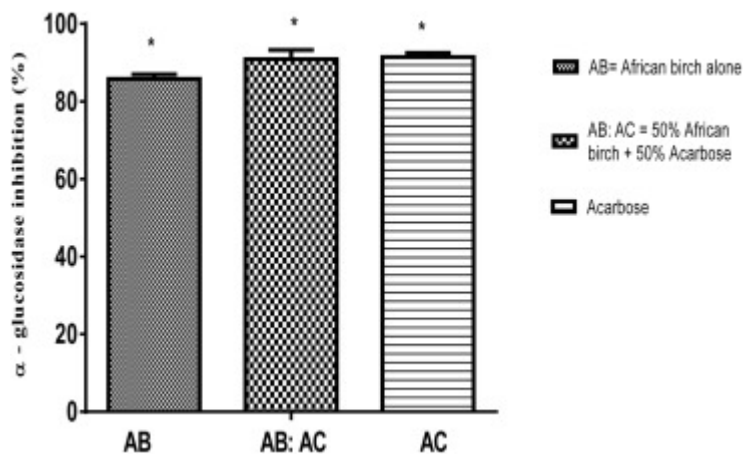
African birch leaf extract (50%

(***)] on bar chart indicate significant ($p < 0.05$) difference between African birch leaves, acarbose and mixture of acarbose and African birch.



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Figure 3. Inhibition of α -glucosidase activities (%) by African birch leaf extract and acarbose. The concentrations of the extract used for the plot are 0.00, 0.20, 0.40, 0.6 and 0.80 mg/mL for the values 0, 1, 2, 3 and 4 respectively as indicated on the x-axis of the graph. The concentrations of the acarbose used for the plot are 0.00, 20.00, 40.00, 60.00 and 80.00 μ g/mL for the values 0, 1, 2, 3 and 4 as shown on the x-axis of the graph. Values represent mean of standard deviation of triplicate readings.



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Figure 4. Inhibition of α -glucosidase activities (%) by African birch leaf extract, combination of African birch leaf extract (50%) and acarbose (50%) and Acarbose alone. (*) on the bar chart indicates non significant ($p > 0.05$) difference.

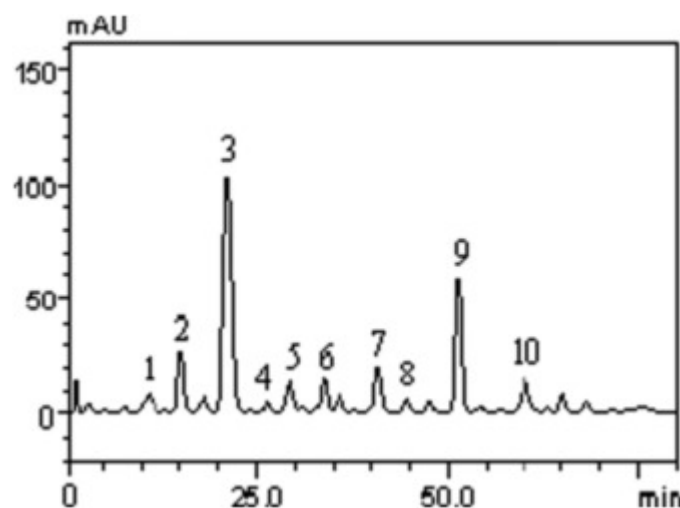
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Figure 5. Representative high performance liquid chromatography profile of African birch leaf. Gallic acid (peak 1), catechin (peak 2), chlorogenic acid (peak 3), caffeic acid (peak 3), ellagic acid (peak 5), epicatechin (peak 6), rutin (peak 7), quercitrin (peak 8), quercetin (peak 9) and kaempferol (peak 10).

Discussion

Total phenolic and flavonoid contents

One of the most abundant antioxidants in plants is polyphenols, which are widely distributed across several food products such as herbs, vegetables, cereals, olive, dry legumes, chocolate and beverages.²² In this study, the total phenol content of African birch was lower than that reported in a previous study from our laboratory on *Crassocephalum crepidioides* leaf, but it had a higher total flavonoid content than that of *C. crepidioides*.²³ Additionally, the phenolic content of African birch was significantly ($p < 0.05$) higher than that of *Celosia* spp, as reported by Molehin et al.²⁴

Antioxidant properties of African birch leaf

Growing scientific evidence s

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of diabetic complications.²⁵ The use of antioxidant supplementation in reducing the level of oxidative stress and in slowing or preventing the development of complications associated with diseases have shown promising therapeutic effects.^{4, 5, 16, 26} Many synthetic antioxidant components have shown toxic and/or [mutagenic effects](#). Hence, much attention has been given to naturally occurring antioxidants.²⁶ Numerous plant constituents have shown free radical scavenging or antioxidant activity.^{14, 23, 24, 26} The free radical scavenging abilities, prevention of iron chelating ability and [lipid peroxidation](#) (Table 3) exhibited by African birch may be part of the mechanism through which African birch leaf exerts its biological activities, which may be responsible for its use in folkloric medicine as an [antidiabetic agent](#).

Effect of African birch leaf extract on the inhibitory properties of acarbose against α -amylase and α -glucosidase activities

The inhibition of [\$\alpha\$ -amylase](#) and [\$\alpha\$ -glucosidase](#) activities by African birch extract suggests the scientific basis for its folkloric use in the management/treatment of [diabetes](#) and could be of great importance in the development of a modern therapeutic in the management of T2D.^{4, 16} Furthermore, [chlorogenic acids](#) and [quercetin](#) were abundant compared with other phenolics found in African birch leaf. A recent report showed that caffeic and chlorogenic acids are good inhibitors of α -amylase and α -glucosidase activities.²⁷ Therefore, we suggest that the inhibition of α -amylase and α -glucosidase activities by plants and plant foods may be attributed to their phenolic constituents.^{23, 27} This agrees with some studies where the inhibition of key enzymes (α -amylase and α -glucosidase) relevant to T2D by plants has been suggested as a therapeutic approach in the management of this disease, and some vital bioactive compounds, including polyphenols, may possess interesting structure-function benefits and promising potential.^{5, 16} The increased inhibition in α -amylase activity by [acarbose](#) and African birch extract when combined (50:50) resulted in an additive effect (Figure 2), whereas the combination of both acarbose and leaf extract caused a synergistic effect on their inhibition of α -glucosidase *in vitro* (Figure 4). The herb–food interaction may have a beneficial effect by increasing [drug efficacy](#) or diminishing potential side effects, as this was validated in our results (Figure 2, Figure 4). Findings from this study correlate with those from an earlier study by Boath et al.,²² who affirmed that synergies between acarbose and berry extracts in diabetes treatment/management may enhance the [hypoglycaemic effect](#) and the inhibition of α -glucosidase activity.

Conclusion

This study reports the [antioxidant activities](#) of African birch leaf and the additive actions and synergistic interaction between African birch leaf and [acarbose](#) in inhibiting [\$\alpha\$ -amylase](#) and [\$\alpha\$ -glucosidase](#) activities, respectively. However, these effects could be attributed to some phenolic components in African birch leaf.

Conflict of interest

The authors have no conflict

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Funding

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Ethical approval

The ethics committee of the School of Sciences, Federal University of Technology, Akure, Nigeria gave approval for the use of laboratory animals (Ref: FUTA/SOS/1399). The ethical regulations are in accordance with national and institutional guidelines for the protection of animal welfare during experiments.

Authors' contributions

SAA and GO conceived the idea and designed the work, interpreted the data, performed the statistical analysis, purchased chemicals and reagents needed for the experiments and addressed the reviewers' comments. OSO, TOJ and SIO were students who participated in all experimental analyses and made the initial draft of the paper.



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References

- 1 World Health Organization
Definition, diagnosis and classification of diabetes mellitus and its complications
Report of WHO Consultation
WHO, Geneva (1999), p. 66
[Google Scholar](#)
- 2 C. Willi, P. Bodenmann, W.A. Ghali, F.D. Faris, J. Cornuz
Active smoking and the risk of type 2 diabetes: a systematic review and meta-analysis
J Am Med Assoc, 298 (2007), pp. 2654-2664
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 3 S. Wild, G. Roglie, A. Gracia, R. Sacre, H. King
Global prevalence of diabetes
Diabetes Care, 27 (2004), pp. 1047-1053
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)

- 4 G. Oboh, A.J. Akinyem
Inhibitory effect of aqueous extract of *Anogeissus leiocarpus* leaf on α -amylase and α -glucosidase activities in type-2 diabetes
J Food Nutr Res, 49 (2010), pp. 14-20
[View Record in Scopus](#) [Google Scholar](#)
- 5 Y.I. Kwon, E. Apostolidis, Y.C. Kim, K. Shetty
Health benefits of traditional corn, beans and pumpkin: *in vitro* studies for hyperglycemia and hypertension management
J Med Food, 10 (2) (2007), pp. 266-275
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 6 S. Kumar, S. Narwal, V. Kumar, O. Prakash
Alpha-glucosidase inhibitors from plants: a natural approach to treat diabetes
Pharmacog Rev, 5 (2011), pp. 19-29
[View Record in Scopus](#) [Google Scholar](#)
- 7 A.Y. Cheng, I.G. Fantus
Oral antihyperglycemic therapy for type 2 diabetes mellitus
Can Med Assoc J, 172 (2005), pp. 213-226
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 8 A.A. Elujoba, O.M. Odeleye, C.M. Ogunyemi
Traditional medicine development for medical and dental primary health care delivery system in Africa
Afr J Tradit Complement Altern Med, 2 (1) (2005), pp. 46-61
[View Record in Scopus](#) [Google Scholar](#)
- 9 M. Sacande, S. Sanogo
***Anogeissus leiocarpus* (DC.) Guill and Perr**
Seed Leaflet (2007), p. 119
[Google Scholar](#)
- 10 K. Batawila
Antifungal activities of five Combretaceae used in Togolese traditional medicine
Fitoterap, 76 (2005), pp. 264-268
[Article](#) [Download PDF](#) [View Record in Scopus](#) [Google Scholar](#)
- 11 S.E. Atawodi, O.O. Adekunle, I. Bala
Antioxidant, organ protective and ameliorative properties of methanol extract of *Anogeissus leiocarpus* leaf against carbon tetrachloride-induced liver injury
Int J Pharm Sci Res, 2 (6) (2011), pp. 1443-1448
[View Record in Scopus](#) [Google Scholar](#)

- 12 E.U. Etuk, B.J. Moham
Informant consensus  [Outline](#)  [Download](#) [Share](#) [Export](#)
in north western Nigeria for the treatment of diabetes mellitus
Afr J Pharm Pharmacol, 3 (2009), pp. 496-500
[View Record in Scopus](#) [Google Scholar](#)
- 13 S.A. Adefegha, G. Oboh
Enhancement of total phenolics and antioxidant properties of some tropical green leafy vegetables by steam cooking
J Food Process Preserv, 35 (2011), pp. 615-622
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 14 V.L. Singleton, R. Orthofor, R.M. Lamuela-Raventos
Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent
Method Enzymol, 299 (1999), pp. 152-178
[Article](#)  [Download PDF](#) [View Record in Scopus](#) [Google Scholar](#)
- 15 A. Meda, C.E. Lamien, M. Romito, J. Millogo, O.G. Nacoulma
Determination of the total phenolic, flavonoid and proline contents in Burkina Faso honey, as well as their radical scavenging activity
Food Chem, 91 (2005), pp. 571-587
[View Record in Scopus](#) [Google Scholar](#)
- 16 S.A. Adefegha, G. Oboh, O.M. Adefegha, A.A. Boligon, M.L. Athayde
Antihyperglycemic, hypolipidemic, hepatoprotective and antioxidative effects of dietary clove (*Syzygium aromaticum*) bud powder in a high-fat diet/streptozotocin-induced diabetes rat model
J Sci Food Agric, 94 (2014), pp. 2726-2737
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 17 M.A. Gyamfi, M. Yonamine, Y. Aniya
Free-radical scavenging action of medicinal herbs from Ghana: *Thonningia sanguinea* on experimentally-induced liver injuries
Gen Pharmacol, 32 (1999), pp. 661-667
[Article](#)  [Download PDF](#) [View Record in Scopus](#) [Google Scholar](#)
- 18 B. Halliwell, J.M.C. Gutteridge
Formation of a thiobarbituric-acid- reactive substance from deoxyribose in the presence of iron salts: the role of superoxide and hydroxyl radicals
FEBS Lett, 128 (1981), pp. 347-352
[Article](#)  [Download PDF](#) [CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)

- 19 G. Minnoti, S.D. Aust
An investigation into  [Outline](#)  [Download](#) [Share](#) [Export](#)
Free Rad Biol Med, 3 (1987), pp. 577-587
[Google Scholar](#)
- 20 H. Ohkawa, N. Ohishi, K. Yagi
Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction
Anal Biochem, 95 (1979), pp. 351-358
[Article](#)  [Download PDF](#) [View Record in Scopus](#) [Google Scholar](#)
- 21 V. Worthington
Alpha amylase
K. Worthington, V. Worthington (Eds.), Worthington enzyme manual, Worthington Biochemical Corp, Freehold NJ (1993), pp. 36-41
[View Record in Scopus](#) [Google Scholar](#)
- 22 A.S. Boath, D. Stewart, G.J. McDougall
Berry components inhibit α -glucosidase in vitro: synergies between acarbose and polyphenols from black currant and rowanberry
Food Chem, 132 (2012), pp. 929-936
[Article](#)  [Download PDF](#) [View Record in Scopus](#) [Google Scholar](#)
- 23 S.A. Adefegha, G. Oboh, O.R. Molehin, J.A. Saliu, M.L. Athayde, A.A. Boligon
Chromatographic fingerprint analysis, acetylcholinesterase inhibitory properties and antioxidant activities of redflower ragleaf (*Crassocephalum crepidioides*) extract
J Food Biochem, 40 (2016), pp. 109-119
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 24 O.R. Molehin, S.A. Adefegha, G. Oboh, J.A. Saliu, M.L. Athayde, A.A. Boligon
Comparative study on the phenolic content, antioxidant properties and HPLC fingerprinting of three varieties of *Celosia species*
J Food Biochem, 38 (2014), pp. 575-583
[CrossRef](#) [View Record in Scopus](#) [Google Scholar](#)
- 25 J.S. Johansen, A.K. Harris, D.J. Rychly, A. Ergul
Oxidative stress and the use of antioxidants in diabetes
Link Diabetol, 4 (2005), pp. 5-6
[CrossRef](#) [Google Scholar](#)
- 26 G. Oboh, S.A. Adefegha, A.O. Ademosun, D. Unu
Effects of hot water treatment on the phenolic phytochemicals and antioxidant activities of Lemon grass (*Cymbopogon citratus*)
Elect J Agric Food Chem, 9 (3) (2010), pp. 503-513

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27

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Caffeic and chlorogenic acids inhibit key enzymes linked to type-2 diabetes (*in vitro*): a comparative study

J Basic Clin Physiol Pharmacol, 26 (2) (2015), pp. 165-170

[View Record in Scopus](#) [Google Scholar](#)

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