

**INHIBITORY EFFECT OF AQUEOUS EXTRACTS OF RAW AND ROASTED  
 SESAMUM INDICUM L. SEEDS ON KEY ENZYMES LINKED TO TYPE-2  
 DIABETES ( $\alpha$ -AMYLASE AND  $\alpha$ -GLUCOSIDASE) AND ALZHEIMER'S DISEASE  
 (ACETYLCHOLINESTERASE AND BUTYRYLCHOLINESTERASE)**

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#### ABSTRACT

Sesame (*Sesamum indicum* L.) seeds are nutritional food, but researches have limited knowledge about the antioxidant, antidiabetic and anticholinesterase activities of the seed. This study was conducted to determine the antioxidant activity, enzyme inhibitory potential ( $\alpha$ -amylase and  $\alpha$ -glucosidase) and acetylcholinesterase inhibitory property of aqueous extracts of raw and roasted sesame seeds. Antioxidant activities were analyzed using 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging property, 2,2-azino-bis-(3-ethylbenthiazoline-6- sulphonic acid (ABTS) scavenging ability, iron chelating ability and ferric reducing antioxidant power (FRAP). Anti-Alzheimer's potential was determined using acetylcholinesterase and butyrylcholinesterase enzyme inhibition assay. The results showed that the total phenolic and flavonoid contents were higher in the roasted *S. indicum* sample with the values of 19.81mg/100g and 17.19 mg/100g respectively. The raw *S. indicum* sample showed higher antioxidant activity in DPPH, and iron chelation assays; while roasted *S. indicum* sample showed higher in the reducing power and ABTS scavenging activity. However, anticholinesterase activity was higher in the roasted *S. indicum* sample than in the raw *S. indicum* sample. The extracts inhibited  $\alpha$ -amylase activity in a concentration-dependent manner (20 – 100  $\mu\text{g.mL}^{-1}$ ). The raw sample (16.55  $\pm$  0.89%) had higher inhibitory  $\alpha$ -amylase activity compared to the roasted sample (15.78  $\pm$  0.48%) at 100  $\mu\text{g.mL}^{-1}$ . Inhibition of  $\alpha$ -glucosidase was higher in the roasted sample at 100  $\mu\text{g.mL}^{-1}$  (19.40  $\pm$  0.26%) compared to the raw sample at the same concentration (3.65  $\pm$  0.52%). These findings suggest that *S. indicum* L. is not only nutritious but also showed potential pharmacological properties.

**Keywords:** *Sesamum indicum* seeds;  $\alpha$ -amylase;  $\alpha$ -glucosidase; anticholinesterases; antioxidant activity; Alzheimer's disease

#### INTRODUCTION

Free radicals have been implicated as playing a role in the etiology of cardiovascular disease, cancer, diabetes mellitus, Alzheimer's disease and Parkinson's disease (Enujigha et al., 2012; Ojo et al., 2017a). Evaluation of the antioxidant activities of natural substances has been of interest in recent years. Antioxidants scavenge free radicals and reactive oxygen species and can be extremely important in inhibiting oxidative mechanisms that lead to degenerative diseases (Enujigha et al., 2012). The antioxidant capacity of most plant food sources is usually associated with their phenolic contents. Since the well-known synthetic antioxidants, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) are reported to confer some degree of carcinogenicity (Enujigha, 2010;

Ojo et al., 2014). Current research efforts are channeled towards exploiting the antioxidant potentials of natural phenolic. Such compounds are found to be abundant in fruits, vegetables, cereal, grains, and legumes.

Sesame (*Sesamum indicum* L.) belongs to the family of Pedaliaceae and is one of the most ancient crops and oilseeds known and used by mankind. It is known as benniseed. In Nigeria, sesame seed is known and called by different vernacular names depending on locality like: 'Ridi' (Hausa), 'Ishwa' (Tiv), 'Yamati or 'Eeku' (Yoruba), 'Igorigo' 'Igbira' and 'Doo' (Jukun). Fibers from sesame are used as an antidiabetic, anti-tumor, antiulcer, cancer preventive and cardio protective (Nagendra-Prasad et al., 2012). In recent years, studies have implicated oxidative stress to play a crucial role in neurodegenerative diseases

such as Alzheimer's disease via lipid peroxidation of the cell membrane of the neurons. It is therefore expedient to assess the inhibitory effect of aqueous extract of sesame seeds on the key enzymes linked to type-2 diabetes and Alzheimer's disease in order to provide some possible mechanism of action by which they exert their anti-diabetic and/or anti-Alzheimer's properties.

### Scientific hypothesis

Scientists have noted that natural plants product with secondary metabolites such as phenols, flavonoids, saponins, tannins have the potentials and/or ability to scavenge free radicals induced oxidative damage. Hence, the higher the polyphenolic content of an extract the higher its potency to inhibit free radical induced oxidative damage.

## MATERIAL AND METHODOLOGY

### Sample collection

Raw sesame seeds were procured for analysis from a local market in Ado-Ekiti. The sample preparation was done at Human Nutrition and Dietetics laboratory, Afe Babalola University Ado-Ekiti. Dirt and other foreign materials were removed from the seeds and by hand picking. The samples were divided into two; raw and roasted. For the roasted sample, the seeds were dry-heated with an open hot plate at 135 °C for 25 mins. During this process, frequent agitation of seed was done for uniform roasting of seeds. The seed sample was ground into a fine powder. The raw and roasted samples were ground separately using a blender.

### Aqueous Extract Preparation

The aqueous extracts of the seeds were prepared by soaking 50 g of the ground samples in 500 mL of distilled water for 48 hr according to (Ojo et al., 2013a). The mixture was later filtered through Whatman filter paper, the filtrate was lyophilized and the dry extract was kept for further analysis.

## In vitro antioxidant determination

### DPPH radical assay

The radical scavenging ability of the extract against 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical was assessed as described by (Gyamfi et al., 1999). 1.0 mL of various concentrations of the extracts in methanol was added to 4 mL of 0.1 mmol.L<sup>-1</sup> methanol solution of DPPH. A blank probe was obtained by mixing 4 mL of 0.1 mmol.L<sup>-1</sup> methanol solution of DPPH and 200 µL of deionized distilled water (H<sub>2</sub>O). After 30 mins of incubation in the dark at room temperature, the absorbance was read at 517 nm against the prepared blank. Inhibition of free radicals by DPPH in percent was calculated using this formula:

$$\% \text{ inhibition} = \frac{ABS_{\text{sample}} - ABS_{\text{blank}}}{ABS_{\text{control}}} \times 100$$

### Iron (Fe<sup>2+</sup>) chelating ability

Fe<sup>2+</sup> chelating ability of the extract was determined using a modified method of (Puntel et al., 2005). Freshly prepared 500 µM FeSO<sub>4</sub> (150 µL) was added to a reaction mixture containing 168 µL 0.1 M Tris-HCl (pH 7.4), 218 µL saline, and the extracts (0 – 25 µL). The reaction mixture was incubated for 5 min, before the addition of 13 µL 0.25% 1,10-phenanthroline (w/v). The absorbance was measured at 510 nm. The Fe (II) chelating ability was subsequently calculated.

### 2,2'-Azinobis (3-ethylbenzo-thiazoline-6-sulfonate) (ABTS) radical scavenging ability

The ABTS' scavenging ability of the extracts was determined according to the method described by (Re et al., 1999). ABTS\* was generated by reacting an ABTS aqueous solution (7 mmol.L<sup>-1</sup>) with potassium persulfate (K<sub>2</sub>S<sub>2</sub>O<sub>8</sub>) (2.45 mmol.L<sup>-1</sup>, final concentration) in the dark for 16 h and adjusting the absorbance 734 nm. 0.2 mL of an appropriate dilution of the extract was added to 2.0 mL ABTS' solution and the absorbance was read at 734 nm after 15mins.



Figure 1 Sesame Seed.

#### Ferric reducing antioxidant assay power (FRAP)

The reducing property of the *S. indicum* seeds aqueous extracts were studied by assessing the ability of the extracts to reduce ferric chloride (FeCl<sub>3</sub>) solution as described by (Pulido et al., 2000). A 2.5 mL aliquot was mixed with 2.5 mL of 200 mM sodium phosphate buffer (pH 6.6) and 2.5 mL of 1% potassium ferricyanide (K<sub>3</sub>[Fe(CN)<sub>6</sub>]). Solution was incubated for 20 min at 50 °C in a water bath and then 2.5 mL of 10% trichloroacetic acid (CCl<sub>3</sub>COOH) was added. The sample was then centrifuged at 650 g for 10 min. After that, 5 mL of the supernatant was mixed with an equal water volume and one mL, 0.1% FeCl<sub>3</sub>. The above-stated process was applied to a standard ascorbic acid solution, and finally the absorbance was read at 700 nm. The reducing ability was calculated as percentage inhibition.

#### Quantification of Phenolic Compounds

##### Estimation of total phenol content

The total phenol content of the seeds extracts was assessed (as gallic acid equivalent) as described by (McDonald et al., 2001). In short, 200 µL extract dissolved in 10% DMSO (240 µg.mL<sup>-1</sup>) was incubated with 1.0 mL of Folin Ciocalteu chemical agent (diluted 10 times) and 800 µL of 0.7 mol.L<sup>-1</sup> sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>) for 30 min at ambient temperature. Absorbance was read at 765 nm using spectrophotometer. All readings were repeated in triplicate. Results expressed as mg GAE.100 g<sup>-1</sup> dry aqueous extracts.

##### Determination of Flavonoid Content

The flavonoid content of the seeds extracts was determined using the method reported by (Meda et al., 2005). Briefly, 0.5 mL of appropriately diluted sample was mixed with 0.5 mL methanol, 50 µL 10% AlCl<sub>3</sub>, 50 µL 1 M potassium acetate and 1.4 mL water, and incubated at room temperature for 30 min. Absorbance of the mixture was read at 415 nm. All experiments were in triplicates. A standard curve was plotted with quercetin and the total flavonoid content of the extract was expressed as quercetin equivalent.

#### Enzymes assays

##### $\alpha$ -amylase inhibition activity assay

The  $\alpha$ -amylase inhibitory activity was determined concurring to the protocol described by (Shai et al., 2010). A volume of 250 µL of aqueous seeds extracts at totally different concentrations (20 – 100 µg.mL<sup>-1</sup>) were incubated with 500 µL of porcine pancreatic amylase (2 U.mL<sup>-1</sup>) in 100 mmol.L<sup>-1</sup> phosphate buffer (pH 6.8) at 37 °C for 20 min. Two hundred and fifty µL of 1% starch dissolved in 100 mmol.L<sup>-1</sup> phosphate buffer (pH 6.8) was then added to the reaction mixture and incubated at 37 °C for 1 h. One mL of DNS color chemical reagent was then added and boiled for 10 min. The absorbance of the resulting mixture was read at 540 nm and the inhibitory activity was expressed as percentage of a control sample without inhibitors. All assays were applied in triplicate.

$$\alpha\text{-amylase inhibition (\%)} = \frac{A_{540}\text{control} - A_{540}\text{sample}}{A_{540}\text{control}} \times 100$$

##### $\alpha$ -glucosidase inhibition activity assay

The  $\alpha$ -glucosidase inhibitory activity was assessed in line with the protocol described by (Ademiluyi and Oboh, 2013), with small modifications. Briefly, 250 µL of aqueous seed extract, at different concentrations (20 – 100 µg.mL<sup>-1</sup>), were incubated with 500 µL of 1.0 U.mL<sup>-1</sup>  $\alpha$ -glucosidase solution in 100 mmol.L<sup>-1</sup> phosphate buffer (pH 6.8) at 37 °C for 15 min. Thereafter, 250 µL of *p*-nitrophenyl- $\alpha$ -D-glucopyranoside (pNPG) solution (5 mmol.L<sup>-1</sup>) in 100 mmol.L<sup>-1</sup> phosphate buffer (pH 6.8) was added and therefore the mixture was more incubated at 37 °C for 20 min. The absorbance of the free *p*-nitrophenol was read at 405 nm and therefore the inhibitory activity was expressed as percentage of a control sample without inhibitors.

$$\alpha\text{-glucosidase inhibition (\%)} = \frac{A_{405}\text{control} - A_{405}\text{sample}}{A_{405}\text{control}} \times 100$$

#### Determination of Cholinesterase Activity

##### Acetylcholinesterase (AChE) inhibition activity assay

Inhibitory activity of AChE was evaluated by an adapted colorimetric method as described by (Ellman et al., 1961). The AChE activity was determined in a mixture containing 200 µL of a solution of AChE (0.415 U.mL<sup>-1</sup> in 0.1 M phosphate buffer, pH 8.0), 100 µL of a solution of 5,5'-dithiobis (2-nitrobenzoic) acid (DTNB) (3.3 mM in 0.1 M phosphate-buffered solution, pH 7.0) containing NaHCO<sub>3</sub> (6 mM), aqueous seed extracts of *S. indicum*, and 500 µL of 4 phosphate buffer, pH 8.0. After incubation for 20 min at 25 °C, 100 µL of 0.05 mM acetylthiocholine iodide solution was added as the substrate, and AChE activity was assessed as change in absorbance at 412 nm for 3 min at 25 °C using a spectrophotometer. Inhibition of BChE was evaluated by an adjusted colorimetric method as described by (Cunha et al., 2016). The BChE activity was assessed in a mixture comprising 200 µL of a solution of BChE (0.415 U.mL<sup>-1</sup> in 0.1 M phosphate buffer, pH 8.0), 100 µL solution of 5,5'-dithiobis (2-nitrobenzoic) acid (DTNB) (3.3mM in 0.1 M phosphate-buffered solution, pH 7.0) containing NaHCO<sub>3</sub> (6 mM), phenolic extracts, and 500 µL of 4 phosphate buffer, pH 8.0. After incubation for 20 min at 25 °C, 100 µL of 0.05 mM butyrylthiocholine iodide solution was added as the substrate, and BChE activity was determined as change in absorbance at 412 nm for 3 min at 25 °C using a spectrophotometer. The AChE and BChE inhibitory activities were expressed as percent inhibition (%).

#### Statistical analysis

All samples were done in triplicates and expressed and mean  $\pm$  standard error of mean (SEM). Data were obtained from the sample analysis using one-way analysis of variance (ANOVA) at 5% level of significance followed by Duncan Multiple Test, using SPSS 21.0 software package.

RESULTS AND DISCUSSION

Table 1 shows the total phenolics and flavonoids content of aqueous extract of raw and roasted sesame samples. Total phenolics and flavonoid contents were significantly ( $p < 0.05$ ) higher in roasted sample compared to the raw sample. Total flavonoid content of the roasted sample was  $17.19 \mu\text{g}\cdot\text{g}^{-1}$ , while in the raw sample it was  $15.45 \mu\text{g}\cdot\text{g}^{-1}$ . Total phenolic content of the roasted sample was  $18.91 \text{ mg}\cdot 100 \text{ g}^{-1}$  and for the raw sample, it was  $15.36 \text{ mg}\cdot 100 \text{ g}^{-1}$ .

<sup>1</sup>. Many plants are rich sources of phytochemicals, and intake of these plant chemicals has protective potential against degenerative diseases (Chu et al., 2002). Phenolic compounds can protect the human body from free radicals, whose formation is associated with the convectional metabolism of aerobic cells. They are strong antioxidants capable of removing free radicals, chelate metal catalysts, activate antioxidant enzymes, reduce  $\alpha$ -tocopherol radicals and inhibit oxidases (Marin et al., 2004). This

Table 1 Total phenolics and flavonoids contents of aqueous extract of *Sesamum indicum L.*

SAMPLES	TOTAL PHENOLICS (mg.GAE.g <sup>-1</sup> )	TOTAL FLAVONOIDS (mg Quercetin.g <sup>-1</sup> )
RAS	15.36 ±0.68	15.45 ±0.68
RSS	18.91 ±1.39	17.91 ±1.22

Note: Mean ±SEM in triplicates (n = 3), ras: raw sesame sample, rss: roasted sesame sample.

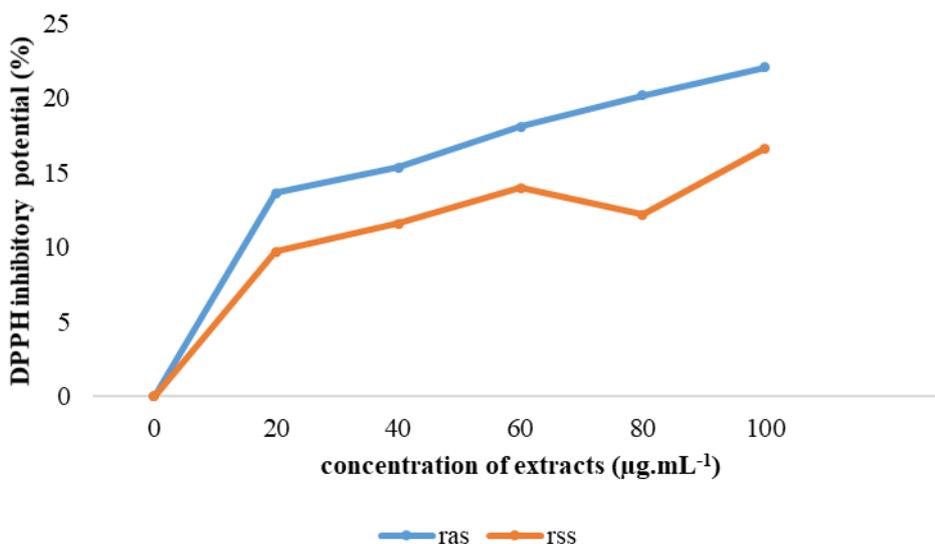


Figure 1 Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against DPPH radical scavenging ability.

Note: Values are represented as the mean ± standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.

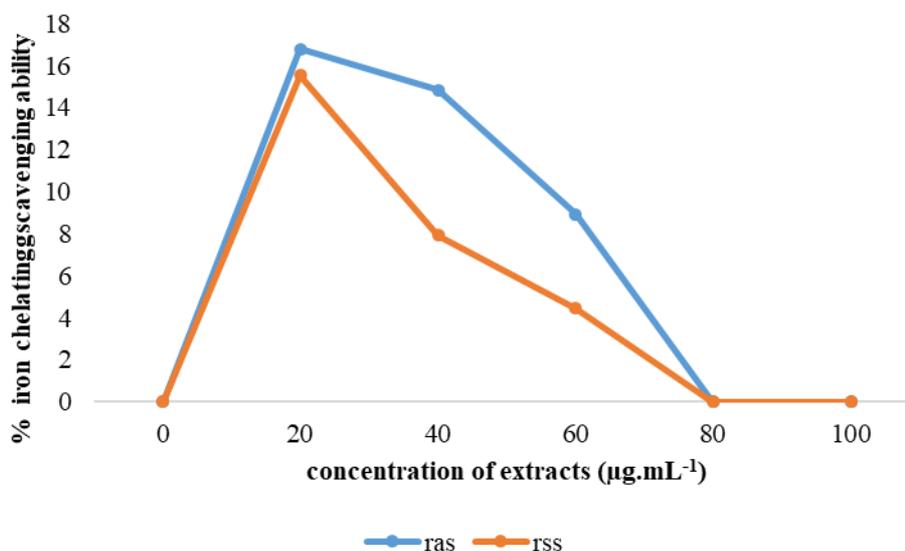


Figure 2 Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against iron chelation.

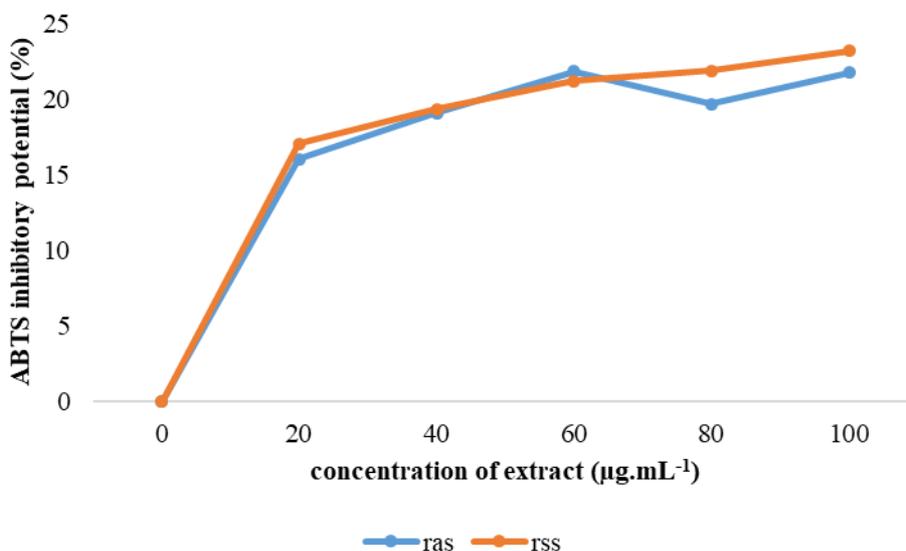
Note: Values are represented as the mean ± standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.

data of analysis confirms previous results reported by (Blessing et al., 2010) who found that sesame seeds possessed the highest amount of flavonoids, compared to other parts of *Sesame indicum*.

Figure 1 shows the DPPH radical scavenging ability of aqueous extracts of sesame (*S. indicum L.*) flour samples. The result of the raw seeds reveals a significant increase ( $p < 0.05$ ) at different concentrations ranging from 20  $\mu\text{g}/\text{mL}$  to 100  $\mu\text{g}/\text{mL}$ . Concentration of 100  $\mu\text{g}/\text{mL}$  had the highest (22.05%) while at 20  $\mu\text{g}/\text{mL}$  was the lowest (16.78%). Similarly, the same trend was observed in the roasted sample with the highest value at 100  $\mu\text{g}/\text{mL}$  (16.62%) and the lowest at 20  $\mu\text{g}/\text{mL}$  (9.70%). Plants and plants products are known to possess excellent antioxidant properties and play a significant role in preventing the complication caused by excessive free radicals (Sharma et al., 2014; Ojo et al., 2013b). The correlation between total

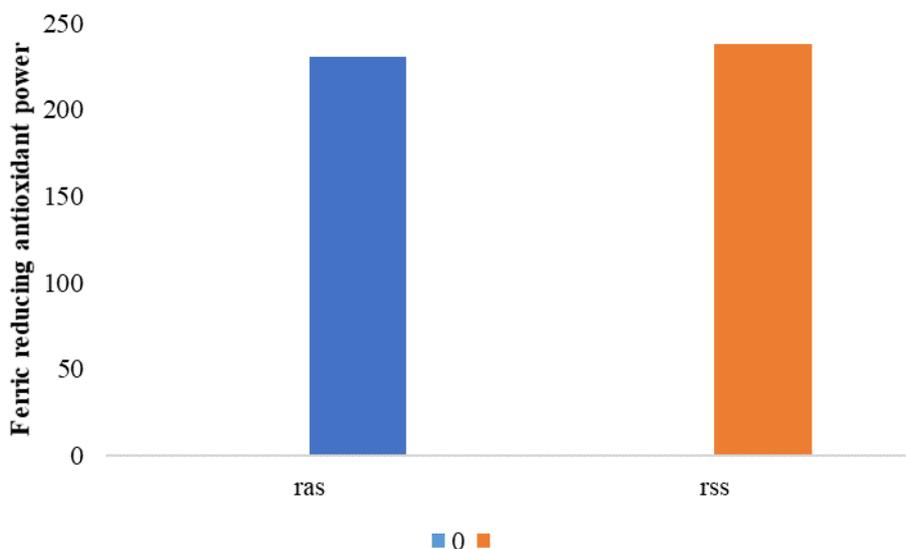
phenol contents and antioxidant activity has been widely studied in different foodstuffs. This study showed that the higher the concentration of the extract, the higher the ability of the seeds extracts to scavenge free radicals. The antioxidant activity increased with increasing concentration of extract. This is in agreement with (Enujigha et al., 2012; Oboh et al., 2007).

Figure 2 shows the iron chelation assay of aqueous extracts of sesame (*S. indicum L.*) flour samples. The results obtained show a significant decrease ( $p < 0.05$ ) at 80 and 100  $\mu\text{g}/\text{mL}$  concentrations in the raw sample. Concentration of 20  $\mu\text{g}/\text{mL}$  (16.78%) had the highest while at 100  $\mu\text{g}/\text{mL}$  there was no inhibition (0.00). The same trend was observed in the roasted sample with the highest at 20  $\mu\text{g}/\text{mL}$  (15.53%) while there was no inhibition at 100  $\mu\text{g}/\text{mL}$ . Iron has been implicated as the most important pro-oxidant of lipids. It is also known that



**Figure 3** Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against ABTS radical scavenging ability.

Note: Values are represented as the mean  $\pm$  standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.



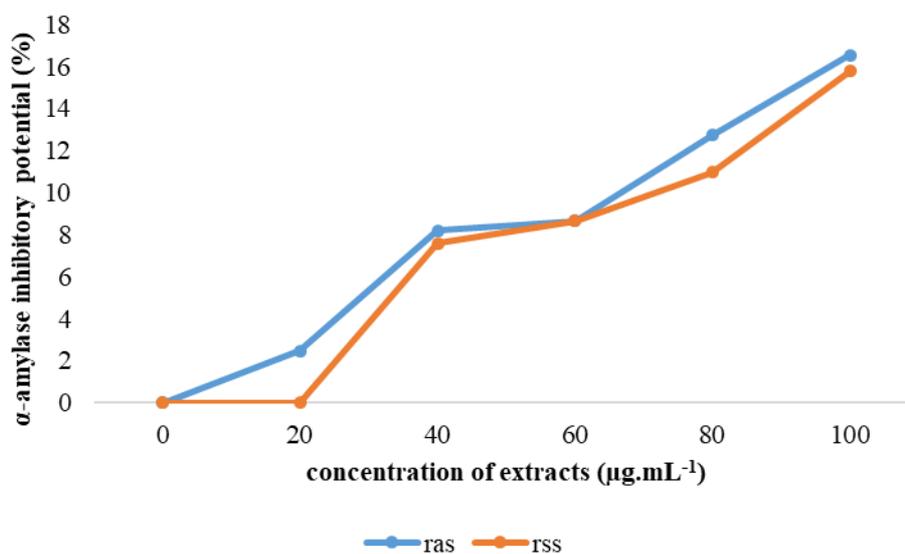
**Figure 4** Ferric reducing antioxidant power of aqueous extract of raw and roasted sesame samples. ras: raw sesame sample, rss: roasted sesame sample.

the  $Fe^{2+}$  accelerates lipid peroxidation by breaking down hydrogen and lipid peroxides formed by the Fenton free radical reaction:  $Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + OH^+ + OH^-$  (Shodeinde and Oboh, 2012). Aqueous seed extract showed more activity in the raw sample compared to the roasted sample but the antioxidant activity decreased with increasing concentration of extract.

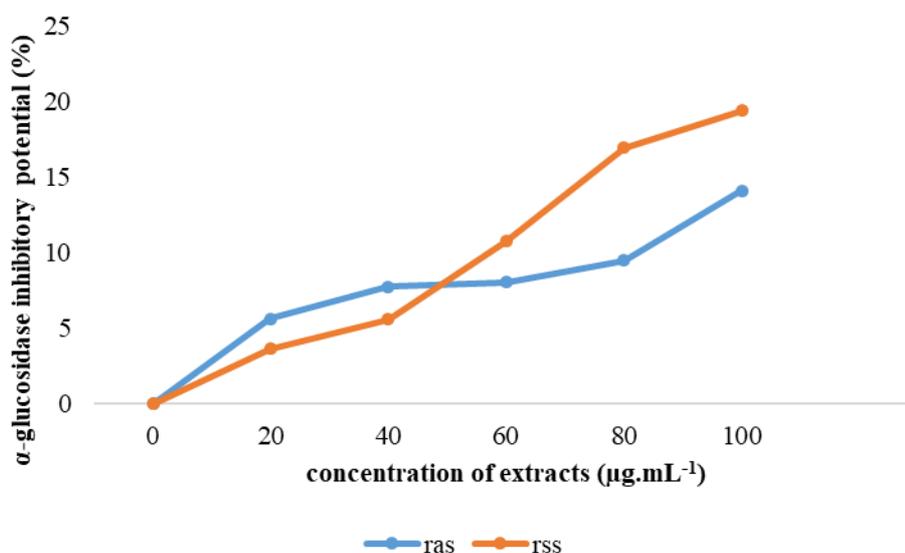
Figure 3 shows the ABTS scavenging capacity of aqueous extracts of sesame (*S. indicum L.*) flour samples. The result obtained in this study shows a significant increase ( $p < 0.05$ ) at different concentrations from (20 – 100  $\mu g \cdot mL^{-1}$ ) in the raw sample. The concentration at 100  $\mu g/mL$  (21.77%) had the highest while at 20  $\mu g \cdot mL^{-1}$  (16.03%) been the lowest. Similarly, the same trend was observed in the roasted sample with concentration at 100  $\mu g \cdot mL^{-1}$  (23.20%) being the highest and concentration

at 20  $\mu g \cdot mL^{-1}$  (17.04%) being the lowest. The principle of ABTS involves the scavenging activity of extracts against free radicals, but ABTS salt must be generated by enzymatic or chemical reaction (Arnao, 2000). In ABTS method, the roasted sample presented more activity than the raw sample.

Figure 4 shows ferric reducing antioxidant power of both raw and roasted sesame samples. FRAP activity was significantly ( $p < 0.05$ ) higher in the roasted sample (237.96  $\mu g \cdot g^{-1}$ ) compared to the raw sample (230.48  $\mu g \cdot g^{-1}$ ). Ferric reducing antioxidant power is one assay to determine the antioxidant capacity in samples which utilize single electron transfer mechanism. In this study, the  $Fe^{3+}$ -tripyrindyl triazine (TPTZ) complex is reduced to the  $Fe^{2+}$ -TPTZ-complex by an antioxidant sample, this latter complex possessing an intense color in



**Figure 5** Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against  $\alpha$ -amylase. Values are represented as the mean  $\pm$ standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.

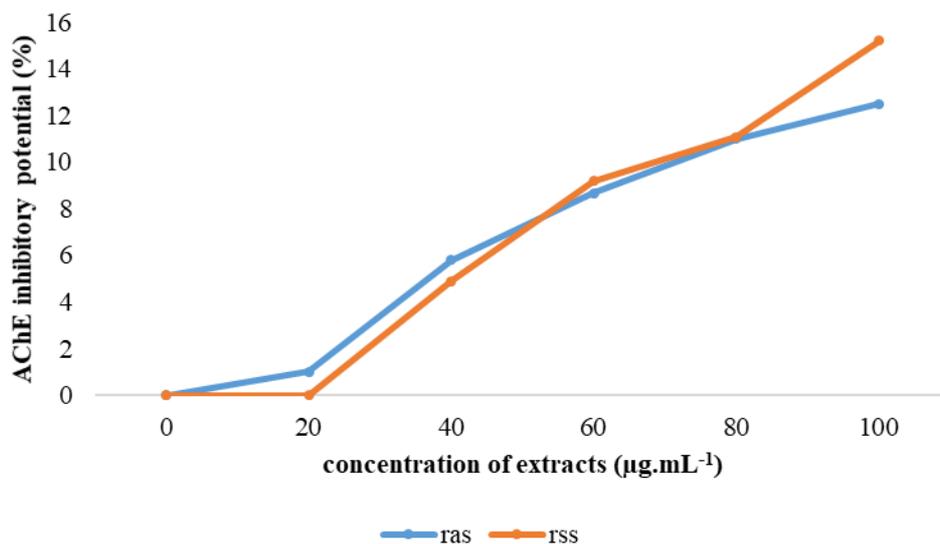


**Figure 6** Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against  $\alpha$ -glucosidase. Note: Values are represented as the mean  $\pm$ standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.

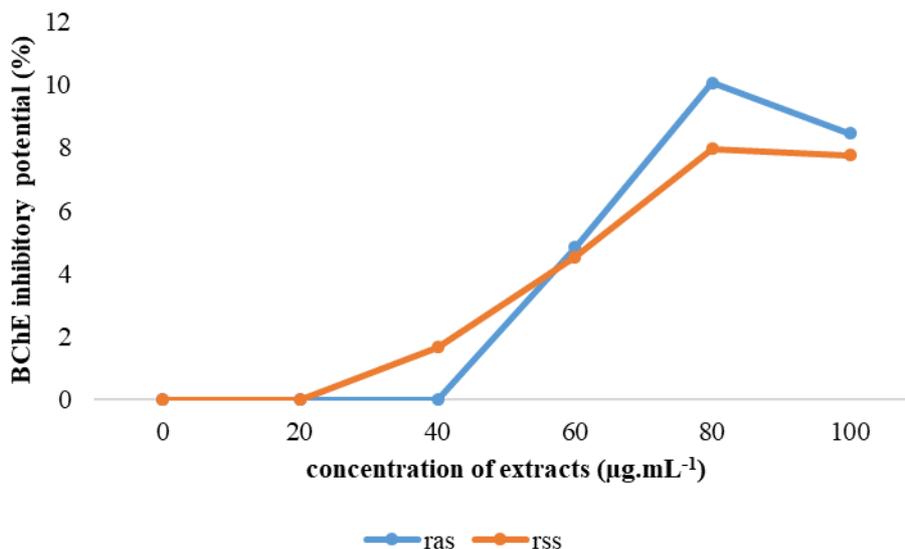
an acidic environment (Ali Hassan et al., 2013). In the present study, the FRAP activity of the roasted sample of *S. indicum* was higher than the raw sample. This finding was higher than that of a previous study by (Siti-Hawa et al., 2013).

Figure 5 shows the inhibitory activity of  $\alpha$ -amylase on aqueous extracts of sesame (*S. indicum L.*) flour samples. The results reveal a significant increase ( $p < 0.05$ ) at different concentrations ranging from 20  $\mu\text{g.mL}^{-1}$  to 100  $\mu\text{g.mL}^{-1}$  in the raw sample. The concentration at 100  $\mu\text{g.mL}^{-1}$  (16.55%) had the highest while at 20  $\mu\text{g.mL}^{-1}$  (2.47%) been the lowest. In the roasted sample, concentration at 100  $\mu\text{g.mL}^{-1}$  (15.78%) had the highest, while there was no inhibition at 20  $\mu\text{g.mL}^{-1}$  (0.00%) concentration. Figure 6 shows the inhibitory properties of  $\alpha$ -glucosidase on aqueous extracts of sesame (*S. indicum L.*) flour samples. Results obtained shows a considerably increase ( $p < 0.05$ ) at different concentrations from

20 – 100  $\mu\text{g.mL}^{-1}$  in the raw sample. The concentration at 100  $\mu\text{g.mL}^{-1}$  (14.10%) had the highest while at 20  $\mu\text{g.mL}^{-1}$  (5.65%) been the lowest. The same trend was observed in the roasted sample, with concentration at 100  $\mu\text{g.mL}^{-1}$  (19.40%) having highest and at 20  $\mu\text{g.mL}^{-1}$  (3.65%) having the lowest. Inhibition of enzymes involved in the hydrolysis of carbohydrates such as  $\alpha$ -amylase and  $\alpha$ -glucosidase has been exploited as a therapeutic approach for controlling postprandial hyperglycemia (Bello et al. 2011; Ojo et al., 2016a). The radical scavenging abilities of the seeds could be beneficial in the management of type 2 diabetes as free radicals are involved in the development and complications of diabetes in a number of ways; the white blood cell production of reactive oxygen species mediates the autoimmune destruction of the beta cells in the islets of Langerhans in the pancreas, abnormalities in transition metal metabolism are postulated to result in the establishment of diabetes, and diabetes associated



**Figure 7** Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against AChE. Note: Values are represented as the mean  $\pm$  standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.



**Figure 8** Inhibitory activities of aqueous extracts from sesame (*Sesamum indicum L.*) seeds against BChE. Note: Values are represented as the mean  $\pm$  standard error of mean of triplicate experiments, ras: raw sesame sample, rss: roasted sesame sample.

hyperglycemia causes intracellular oxidative stress, which contributes to vascular dysfunction (Ademosun and Oboh, 2015). Pancreatic  $\alpha$ -amylase is involved in the breakdown of starch into disaccharides and oligosaccharides before intestinal  $\alpha$ -glucosidase catalyzes the breakdown of disaccharides to liberate glucose which is later absorbed into the blood circulation. Inhibition of these enzymes would slow down the breakdown of starch in the gastrointestinal tract, thus reducing postprandial hyperglycemia (Kwon et al., 2007; Ojo et al., 2016b). The extracts inhibited  $\alpha$ -amylase and  $\alpha$ -glucosidase activities in a concentration-dependent manner. This indicates that both raw and roasted *Sesame indicum* L. are good choices for diabetics, and also that a large amount of the seeds is to be consumed to be effective.

Figure 7 shows the inhibitory effect of AChE on aqueous extracts of sesame (*S. indicum* L.) flour samples. The results reveal a considerably increase ( $p < 0.05$ ) at different concentrations ranging from 20 – 100  $\mu\text{g}\cdot\text{mL}^{-1}$  in the raw sample. The concentration at 100  $\mu\text{g}/\text{mL}$  had the highest (12.51%) while at 20  $\mu\text{g}\cdot\text{mL}^{-1}$  (1.02%) been the lowest. The same trend was observed in the roasted sample with concentration at 100  $\mu\text{g}\cdot\text{mL}^{-1}$  (15.22%) having the highest and concentration at 20  $\mu\text{g}\cdot\text{mL}^{-1}$  (0.00%) having no inhibition. Figure 8 shows the inhibitory effect of BChE on aqueous extracts of sesame (*S. indicum* L.) flour samples. Results showed there was no inhibition at 20 and 40  $\mu\text{g}/\text{mL}$  concentration in the raw sample, but there was a considerably increase ( $p < 0.05$ ) at 60 and 80  $\mu\text{g}\cdot\text{mL}^{-1}$  concentrations. Concentration of 80  $\mu\text{g}\cdot\text{mL}^{-1}$  (10.05 %) had the highest BChE activity. While in the roasted sample, there was no inhibition at 20  $\mu\text{g}\cdot\text{mL}^{-1}$  (0.00%) concentration, but there was an appreciable increase ( $p < 0.05$ ) at 40, 60 and 80  $\mu\text{g}\cdot\text{mL}^{-1}$  concentrations with concentration at 80  $\mu\text{g}\cdot\text{mL}^{-1}$  (7.96%) having the highest. This study showed that both the raw and roasted *S. indicum* L. samples displayed anticholinesterase activity potential which was in a concentration dependent manner. The values obtained for AChE were lower compared to that of aqueous extract of *Glycine max* (68.4%) as reported by (Shariffar et al., 2010). Inhibition of acetylcholinesterase (AChE) activity has been accepted as an effective treatment/management strategy against mild Alzheimer's disease (AD) (Orhan et al., 2004). Alzheimer's disease is a form of dementia characterized by loss of central cholinergic neurons associated with a marked reduction in the content of acetylcholinesterase (AChE), the enzyme responsible for the termination of nerve impulse transmission at cholinergic synapses. Consequently, one therapeutic approach to the treatment of Alzheimer's disease is the use of plant-based anticholinesterase drugs which have little or no side effects (Oboh et al., 2014; Ojo et al., 2017b; Ojo et al., 2018). Hence, inhibition of these cholinesterase's could be as a result of the important phytochemicals such as phenolics and flavonoids which have already been characterized in this extract.

## CONCLUSION

In conclusion, aqueous extract of both raw and roasted sesame seed (*S. indicum* L.) is rich in phenolic compounds and exhibited antioxidant activities. Sesame seeds show potential as functional food and/or nutraceuticals in the

management of diabetes mellitus and neurodegenerative diseases such as Alzheimer's disease as it exhibited inhibitory activity on key enzymes ( $\alpha$ -amylase,  $\alpha$ -glucosidase acetylcholinesterase and butyrylcholinesterase) linked to these diseases. Therefore, one possible mechanism through which the seeds exert their neuroprotective properties is by inhibiting cholinesterase activities as well as preventing oxidative-stress-induced neurodegeneration.

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