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Raffia palm (*Raphia hookeri*) wine: Qualitative sugar profile, functional chemistry, and antidiabetic properties

Ochuko L. Erukainure[a,b], Chika I. Chukwuma[a,c], Md Shahidul Islam[a,*]

[a] Department of Biochemistry, School of Life Sciences, University of KwaZulu-Natal, (Westville Campus), Durban, 4000, South Africa
[b] Nutrition and Toxicology Division, Federal Institute of Industrial Research, Lagos, Nigeria
[c] Department of Health Sciences, Faculty of Health and Environmental Sciences, Central University of Technology, Bloemfontein, 9301, South Africa

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ABSTRACT

The effects of short-term fermentation on the sugar quality, functional chemistry, antioxidant and antidiabetic properties of Raffia palm (*Raphia hookeri*) wine were investigated. Palm wine samples were subjected to open air fermentation for 24 and 48 h. The samples showed significant ($p < 0.05$) antioxidant activities with little or no differences between the unfermented and fermented samples. There was a dose-dependent inhibitory effect on α-glucosidase, α-amylase and intestinal glucose absorption with increasing fermentation time. Both non-fermented and 24 h fermentation led to increased muscle glucose uptake in a dose-dependent manner. ^{1}H NMR spectroscopy showed the presence of allose, cellobiose, d-tagatose, fructose, galactitol, gluconic acid, rhamnose, sucrose, xylose and β-N-acetylglucosamine in the samples. FTIR spectroscopy showed the presence of alcohols, phenols, 1° and 2° amines and aromatics functional groups in all samples. Fermentation led to the addition of the functional group, bend alkenes. These results suggested that un-fermented and fermented Raffia palm wine may have antioxidant and antidiabetic properties.

1. Introduction

Diabetes mellitus (DM) has been recognized as one of the world's growing diseases, and a major contributor of morbidity and mortality in Africa (Motala, 2002). It is a metabolic disease affecting carbohydrate, protein and lipid metabolism, leading to increased blood glucose levels (Saltiel & Kahn, 2001). The inability of the pancreatic β-cells to secrete enough insulin (type 1 diabetes) and the inability of the body to use secreted insulin (type 2 diabetes, T2D) have been reported to be the main causes of DM. T2D is the most prevalent type of diabetes, constituting more than 90% of cases (IDF, 2015). It is characterized by hyperglycemia, which has been implicated in the morbidity and mortality with T2D. Chronic hyperglycemia has been shown to alter the body's redox balance due to increased production of reactive oxygen species (ROS) (Tiwari, Pandey, Abidi, & Rizvi, 2013). Alteration of the body's redox balance in favor of ROS production over the body's antioxidant system will lead to oxidative stress (Erukainure, Mopuri, Oyebode, Koorbanally, & Islam, 2017). Oxidative stress is a major contributor to the pathogenic micro- and macro-vascular complications with T2D (Tiwari et al., 2013). Treatment of T2D with antioxidants has been shown to reduce these complications (Ziegler et al., 2011).

The role of medicinal plants in the treatment and management of T2D and its complications has been reported (Abo, Fred-Jaiyesimi, & Jaiyesimi, 2008; Ezuruike & Prieto, 2014). This has been attributed to their phytochemical and nutritional properties (Patel, Kumar, Laloo, & Hemalatha, 2012). Some of these plants are often used alone or in combinations immersed in fresh (unfermented) or fermented Raffia palm (*Raphia hookeri*) wine.

Palm wine is a traditional beverage with a milky flocculent appearance obtained from the sap of palm trees (Eze & Ogan, 1988; Nwaiwu et al., 2016). It is consumed fresh (unfermented) and fermented. It is consumed across west Africa, India and Indonesia. In Nigeria, its common names include “palmy”, “oguro”, “emu”, “tombo”, “nkwu ocha”, and “nkwu enu”. It is used in most socio-cultural activities in Nigeria, where it is consumed as a traditional beverage (Nwaiwu & Itumoh, 2017) and used in folkloric medicine. Its high content of the yeast, *Saccharomyces cerevisiae*, makes it susceptible to fermentation, leading to decreased sweetness with a concomitant increase in alcohol content. It is a good dietary source of ascorbic acid and the B-vitamins complex, particularly thiamine (Bassir, 1962; Eze & Ogan, 1988; Tuley, 1965). Obahiagbon and Osagie (2007) reported the presence of potassium, magnesium, calcium, sodium, phosphorus, and nitrogen in palm wine. Also, it has sucrose, glucose, xylose, raffinose and lactose (Ezeagu, Fafunso, & Ejezie, 2003; Obahiagbon & Osagie, 2007), which

* Corresponding author.
E-mail address: islamd@ukzn.ac.za (M.S. Islam).

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are responsible for its sweetness.

However, there have been concerns about the safety and efficacy of palm wine in combination with medicinal herbs, particularly in the treatment of T2D, due to the sweetness of its unfermented form and the alcoholic content of its fermented form. Thus, the effects of short-term fermentation on the sugar quality, functional chemistry, antioxidant and anti-diabetic properties of raffia palm (*Raphia hookeri*) wine were investigated.

2. Materials and methods

2.1. Raffia palm wine

Fresh raffia palm wine was purchased from local tappers in August 2017 at Benin City, Nigeria. It was filtered through prewashed cloth to remove any debris. It was divided into 3 batches of 300 mL each. The first batch was concentrated to dryness to a constant weight at 50 °C in a water bath and marked as unfermented. The second and third batches were subjected to open-air fermentation on the bench top in the laboratory (room temperature: 25–28 °C) for 24 h (from 9:00 a.m. of the 1st day until 9:00 a.m. of the 2nd day) and 48 h (from 9:00 a.m. of the 1st day until 9:00 a.m. of 3rd day), respectively, and immediately concentrated like the first batch. The concentrates from the 3 batches were stored in glass vial at 4 °C, until further analysis (not more than 48 h).

A 1 mg/mL stock solution was prepared in distilled water for each of the concentrated samples. Different concentrations of 15, 30, 60, 120 and 240 μg/mL were prepared from the stock solution and these were used for *in vitro* and *ex vivo* studies.

2.2. Total phenolic content

The total phenolic content of the samples was measured using the Folin–Ciocalteu reagent assay using a previous method (Liu & Yao, 2007) with modifications. Briefly, 25 μL of the samples (240 μg/mL) or gallic acid standards (0–480 μg/mL) (Sigma Aldrich, Johannesburg, South Africa) were incubated with 125 μL of 10 times diluted Folin Ciocalteau reagent (Merck, Johannesburg, South Africa) and 100 μL of 0.7 M Na_2CO_3 for 30 min at room temperature in a 96 well plate. Thereafter, absorbance was measured spectrophotometrically at 765 nm using a 96-well plate reader (Synergy HTX Multi-mode reader, BioTek Instruments Inc., Winooski, VT, USA). Phenol content of samples was obtained from a standard curve and the values were expressed as mg gallic acid equivalents (GAE)/g dry weight.

2.3. In vitro antioxidant activity

The 2,2′-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity of the samples was determined using a previous method (Braca, Sortino, Politi, Morelli, & Mendez, 2002) with modifications. Briefly, 160 μL of increasing concentrations (15–240 μg/mL) of the samples or ascorbic acid (positive control) or distilled water (control) and 80 μL of 0.3 mM DPPH were mixed in a 96 well plate and incubated in the dark for 30 min at room temperature. Thereafter, absorbance was measured at 517 nm. The free radical scavenging activity of the samples was calculated using the following formula:

$$\text{Free radical scavenging activity } (\%) = \frac{(A_c - A_t)}{A_c} \times 100$$

Where "A_c" is the absorbance of the control and "A_t" is the absorbance of the samples or positive control.

The ferric reducing antioxidant power (FRAP) of the samples was measured using a previous method (Benzie & Strain, 1996) with modifications. The reaction mixture comprising 50 μL of 15–240 μg/mL of the samples or ascorbic acid (Sigma Aldrich) or 240 μg/mL of gallic acid and 50 μL of 1% potassium ferricyanide (in 0.2 M sodium phosphate buffer, pH 6.6) were incubated at 50 °C for 30 min. Thereafter, 50 μL of 10% TCA, 50 μL of distilled water and 10 μL of 0.1% ferric chloride were consecutively added and the absorbance was measured at 700 nm using the 96-well plate reader. The ferric reducing power of the samples or ascorbic acid (positive control) was expressed as the percentage of the 240 μg/mL gallic acid.

2.4. Carbohydrate digesting enzyme inhibitory activity

The inhibitory effect of the samples on α-glucosidase was measured as the inhibition of paranitrophenyl-α-D-glucopyranoside (Sigma Aldrich) substrate hydrolysis using a previous method (Oboh & Ademosun, 2011) with modifications. One hundred μL of 1 U/mL α-glucosidase (Sigma Aldrich) solution (dissolved in 0.1 M sodium phosphate buffer, pH 6.9) was incubated with 50 μL of the samples or acarbose (Sigma Aldrich) solutions (15–240 μg/mL) or distilled water (control) at 37 °C using a CO_2 incubator (Steri-Cult CO_2 incubator, Labotec, Johannesburg, South Africa) for 15 min. Thereafter, 50 μL of 5 mM paranitrophenyl-α-D-glucopyranoside solution was added to start the enzyme reaction. The reaction mixture was incubated at 37 °C using the incubator for 20 min. Thereafter, the absorbance was measured at 405 nm and the enzyme inhibition of the samples or acarbose (positive control) was computed as a percentage of the control using the previously given formula.

Reducing sugars resulting from starch hydrolysis, using an α-amylase enzyme, can reduce yellow 3,5-dinitrosalicylic acid (DNSA) to a reddish-brown 3-amino-5-nitrosalicylic acid, which can be measured at 540 nm. The inhibitory effect of the samples or standard (acarbose) on porcine pancreatic α-amylase (EC: 3.2.1.1; Sigma Aldrich) activity was determined based on this principle, using a method previously described by Oboh and Ademosun (2011) with modification. Equal volumes (100 μL) of 2 U/mL α-amylase solution (dissolved in the phosphate buffer) and different concentrations (15–240 μg/mL) of the samples or acarbose or distilled water (control) were incubated at 37 °C for 20 min using the incubator. The mixture was then incubated with 100 μL of 1% starch at 37 °C for 1 h, before boiling with 400 μL of DNSA color reagent for 10 min. After cooling, absorbance was measured at 540 nm. The enzyme inhibition of the samples or acarbose was calculated as a percentage of the control using the previously given formula.

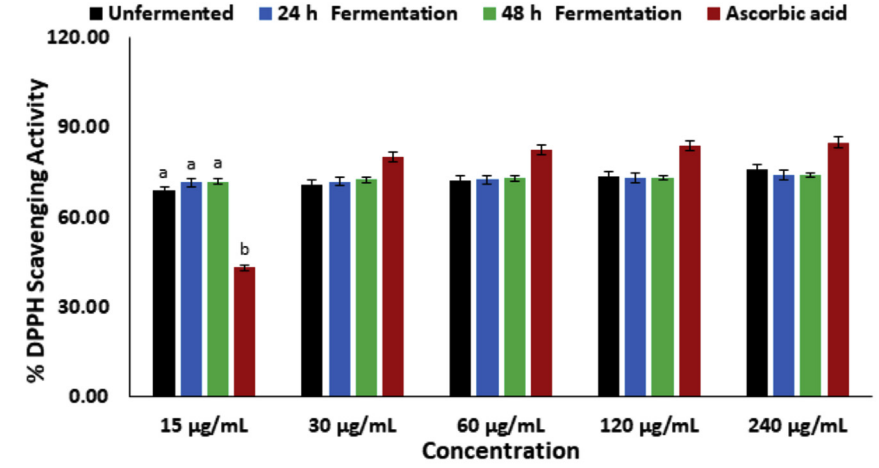
2.5. Animals

Five male albino rats (Sprague Dawley strain) weighing 200–250 g, were obtained from the Biomedical Research Unit (BRU), University of KwaZulu-Natal, Durban, South Africa. The animals fed on commercial chow and water provided *ad libitum*. They were kept two per medium-sized cage in a room with controlled conditions of 12 h light-dark cycle. To do the *ex vivo* experiments, the rats were euthanized with halothane (Sigma Aldrich), after overnight fasting. Their intestines and psoas muscles were harvested, rinsed in 0.9% NaCl solution and used immediately for the glucose uptake and absorption *ex vivo* studies.

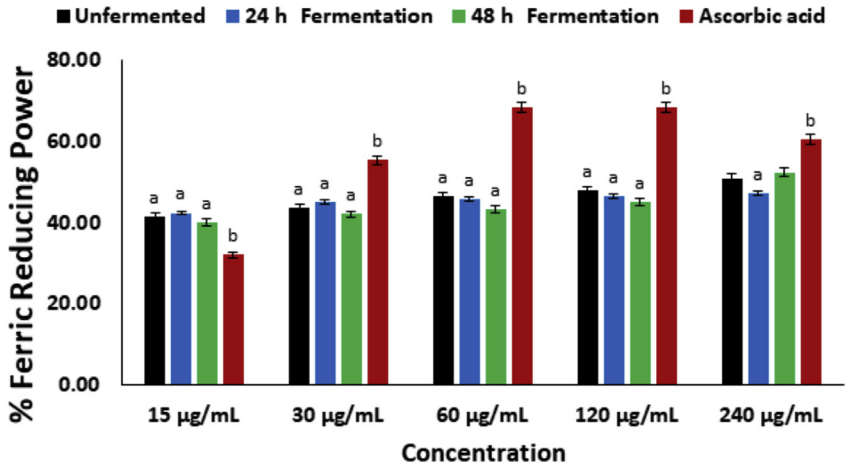
The animals study was in accordance with the approved guidelines of the Animal Ethics Committee of the University of KwaZulu-Natal, Durban, South Africa (Protocol approval number: AREC/020/017D).

2.5.1. Measurement of glucose absorption in isolated rat jejunum

The inhibitory effect of the samples on intestinal glucose absorption was determined by measuring glucose absorption in the presence of the samples using a previous method (Chukwuma, Ibrahim, & Islam, 2016). Five cm segments of isolated rat jejunum were inverted and incubated in 8 mL of Krebs buffer (118 mM NaCl, 5 mM KCl, 1.328 mM $CaCl_2{\cdot}2H_2O$, 1.2 mM KH_2PO_4, 1.2 mM $MgSO_4$ and 25 mM $NaHCO_3$) containing 200 mg/dL glucose with (test) and without (control) of different concentrations (60–240 μg/mL) of the samples. Incubation was done for 2 h at 5% CO_2, 95% oxygen and 37 °C using the incubator. Glucose concentration was measured (Automated Chemistry Analyzer,



(A)



(B)

Fig. 1. (A) DPPH scavenging and (B) FRAP activities of unfermented and fermented Raffia palm wine. Data = mean ± SD; n = 3. "a" and "b" data labels for a given concentration's mean value are significantly ($p < 0.05$) different from each other, when comparing each parameter.

Labmax Plenno, Labtest Inc., Lagoa Santa, Brazil) in the incubation solution before and after incubation and glucose absorption was computed as the decrease of glucose concentration in the incubation solution.

2.5.2. Measurement of glucose uptake in isolated rat psoas muscles

The ability of the samples to increase glucose uptake in isolated rat psoas muscles was determined by measuring glucose uptake in the presence of the samples using a previous method (Chukwuma et al., 2016). Five hundred mg portions of the isolated psoas muscle were incubated in 8 mL of Krebs buffer containing 200 mg/dL glucose with (test) and without (control) different concentrations (60–240 µg/mL) of the samples or 240 µg/mL metformin (Sigma Aldrich). Incubation was done for 1 h at 5% CO_2, 95% oxygen and 37 °C using the CO_2 incubator. Glucose concentration was measured in the incubation solution before and after incubation and glucose uptake was computed as the decrease of glucose concentration in the incubation solution.

2.6. Proton NMR spectroscopy analysis

Briefly, 13 mg each of the samples were dissolved in 0.8 mL D_2O (Merck), filtered through prewashed cotton and then subjected to ^1H NMR spectroscopy (400 MHz; Bruker Corp., Billerica, MA, USA). Chemical shifts were reported in δ (ppm) values. Compounds were identified by direct search and comparison of chemical shift data against the Food Database (FooDB Version 1.0) (FoodDB, 2017). The compounds were drawn using ChemDraw® (Version 16, PerkinElmer, Boston, MA, USA).

2.7. Fourier Transform Infrared spectroscopy (FTIR) analysis

The infrared spectrum of the samples was measured using a Fourier Transform Infrared (FT-IR) spectrometer (PerkinElmer Spectrum 100 FTIR Spectrometer) with the ART accessory at a scan rate of 40 s^{-1} in the resolution range of 4000–380 cm^{-1}. Approximately 1 mg of sample was loaded to cover the crystal of the sample holder. The functional groups were obtained by comparing the peak frequencies to an IR spectroscopy correlation table of the Spectrum 100 FTIR Spectrometer software.

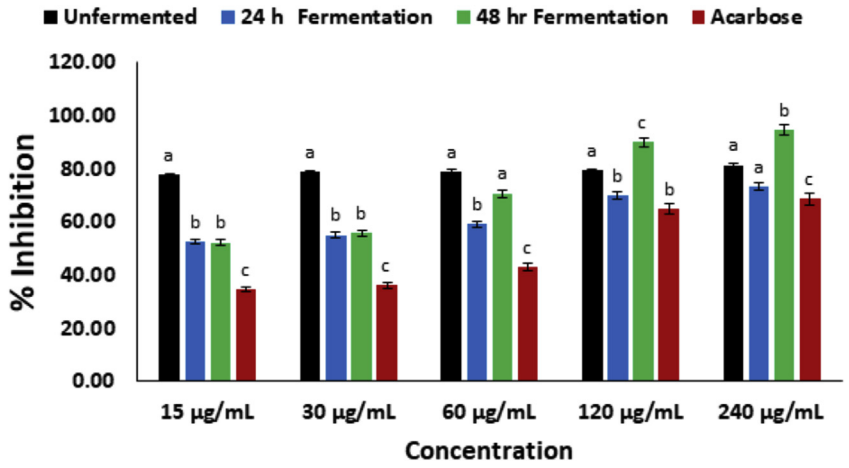
2.8. Statistics

Statistical significance was computed using the one-way analysis of variance (ANOVA), and data were shown as mean ± SD. Significant

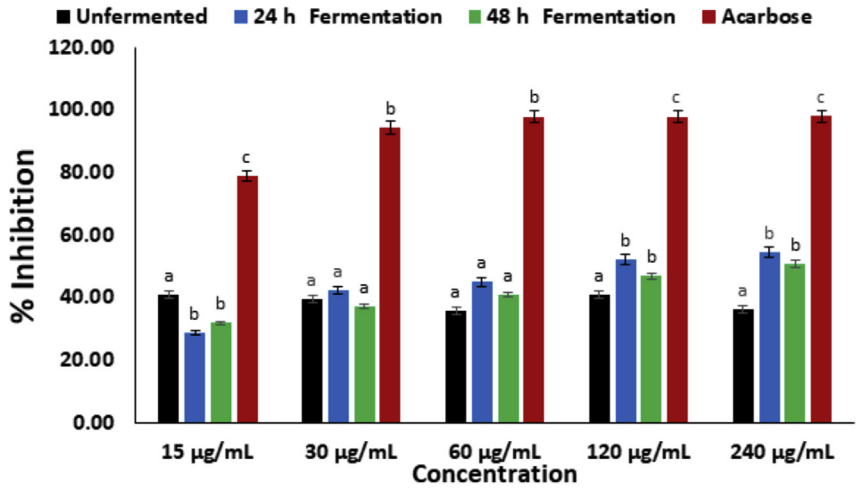
Table 1
IC_{50} values of biological activities of unfermented and fermented Raffia palm wine.

Activities	Unfermented (μg/mL)	24 h Fermented (μg/mL)	48 h Fermented (μg/mL)	Ascorbic Acid (μg/mL)	Acarbose (μg/mL)
DPPH	1.0 ± 0.1	2.0 ± 0.2	2.0 ± 0.3	8.3 ± 1.0	–
FRAP	190 ± 10	980 ± 10	230 ± 30	30 ± 2	–
Alpha glucosidase	6.8 ± 1.0	1.1 ± 0.1	16 ± 1	–	62 ± 9
Alpha amylase	540 ± 20	110 ± 5	30 ± 1	–	0.04 ± 0.01
Glucose absorption	37 ± 2	1.4 ± 0.1	0.5 ± 0.01	–	–
Glucose uptake	12 ± 1	7.1 ± 0.9	100 ± 10	–	–

Values = mean ± SD; n = 3.



(A)



(B)

Fig. 2. (A) Alpha-glucosidase and (B) alpha amylase inhibitory activities of unfermented and fermented Raffia palm wine. Data = mean ± SD; n = 3. "a", "b" and "c" data labels for a given concentration's mean value are significantly ($p < 0.05$) different from each other, when comparing each parameter.

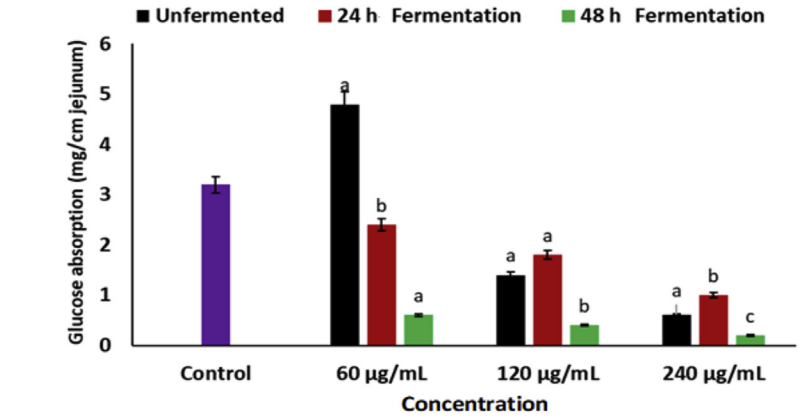
differences between means were obtained at $p < 0.05$, using the Tukey's HSD-multiple range post-hoc test. Statistical analyses were done using IBM Statistical Package for the Social Sciences (SPSS) for Windows, version 23.0 (IBM Corp., Armonk, NY, USA).

3. Results and discussion

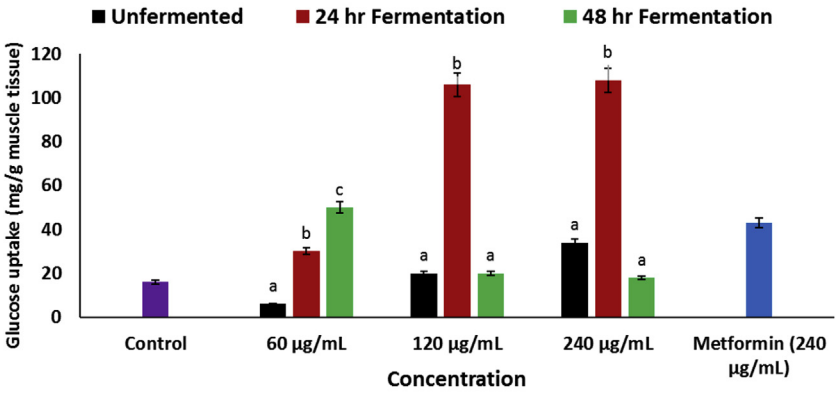
The safety and efficacy of the use of palm wine in combination with antidiabetic medicinal herbs remains a major concern to most health practitioners. This is due to its sweetness and ease of fermentation. In this study, the antidiabetic potential of Raffia palm wine and the influential role of fermentation on its biological activity.

3.1. Total phenolic content

All samples had low total phenolic contents as shown in Suppl. 1. Fermentation for 24 h led to a significant ($p < 0.05$) decrease in the total phenolic content; this was, however, increased after 48 h fermentation. The role of polyphenolics in the medicinal properties of plants is well documented (Erukainure et al., 2017). They are secondary metabolites with reported antioxidant activities (Adedayo, Oboh, & Akindahunsi, 2010).



(A)



(B)

Fig. 3. Effects of fermentation on (A) glucose absorption in isolated rat jejunum and (B) glucose uptake in isolated rat psoas muscle by Raffia palm wine. Data = mean ± SD; n = 3. "a", "b" and "c" data labels for a given concentration's mean value are significantly ($p < 0.05$) different from each other, when comparing each parameter.

3.2. In vitro antioxidant activity

There was with little or no significance difference between the antioxidant activities of the unfermented and fermented palm wine samples as shown in Fig. 1A and 1B. The respective IC_{50} values of the unfermented, 24 h fermented and 48 h fermented samples for DPPH scavenging measurement suggested that they have good radical quenching activities, even higher than that of ascorbic acid (8.3 µg/mL) (Table 1). The respective IC_{50} values of the samples for FRAP measurement, though higher than that of ascorbic, also suggested that they may have strong antioxidant potentials. The role of antioxidants in the amelioration of T2D complications has been reported (Rahimi, Nikfar, Larijani, & Abdollahi, 2005). Thus, suggesting a protective role of Raffia palm wine against hyperglycemia induced oxidative stress. The antioxidant activities are consistent with previous reports on the DPPH scavenging properties of Raffia palm wine (Oboh & Okhai, 2012), which may also be due to the total phenolic content (Suppl. 1).

3.3. Carbohydrate digesting enzyme inhibitory activity

All samples showed significant inhibition of α-glucosidase as shown in Fig. 2A. The unfermented palm wine sample did not show a dose-dependent inhibitory effect. However, the 24 and 48 h fermented samples showed dose-dependent inhibitory effects, with the 48 h sample showing significantly ($p < 0.05$) higher activity than the 24 h at high concentrations. The IC_{50} values for the unfermented, 24 h and 48 h fermented samples showed better α-glucosidase inhibitory activities compared to acarbose, with the 24 h sample showing the best activity (Table 1).

The inhibitory effect of the palm wine samples on α-amylase activity was significantly lower than acarbose as shown in Fig. 2B. All samples showed a dose-dependent inhibitory effect, which also increased with longer fermentation duration. The 48 h fermented palm wine sample had the best activity compared to the other palm wine samples and acarbose, as suggested by its IC_{50} value (Table 1). The inhibition of these enzymes has been linked to the antidiabetic properties of most drugs and medicinal plants (Bischoff, 1995; Oboh, Nwokocha, Akinyemi, & Ademiluyi, 2014). These enzymes are involved in the breakdown of dietary carbohydrate to glucose. Therefore, inhibition of their activities will decrease the amount of glucose absorbed from the small intestine into the blood stream. These results suggested that Raffia palm wine may potentiate glycemic control by inhibiting the breakdown of dietary carbohydrate. Fermentation has been shown to improve the antidiabetic properties of foods (Kwon, Daily, Kim, & Park, 2010), which is consistent with the good inhibitory activities of the fermented samples.

3.4. Glucose absorption inhibitory activity in isolated rat jejunum

Glucose arising from the breakdown of dietary carbohydrate is rapidly absorbed in the small intestine, particularly at the proximal (jejunal and duodenal) regions (Chukwuma, Mopuri, Nagiah, Chuturgoon, & Islam, 2018), which leads to increased blood glucose levels. Incubation of isolated rat jejunum with unfermented and fermented

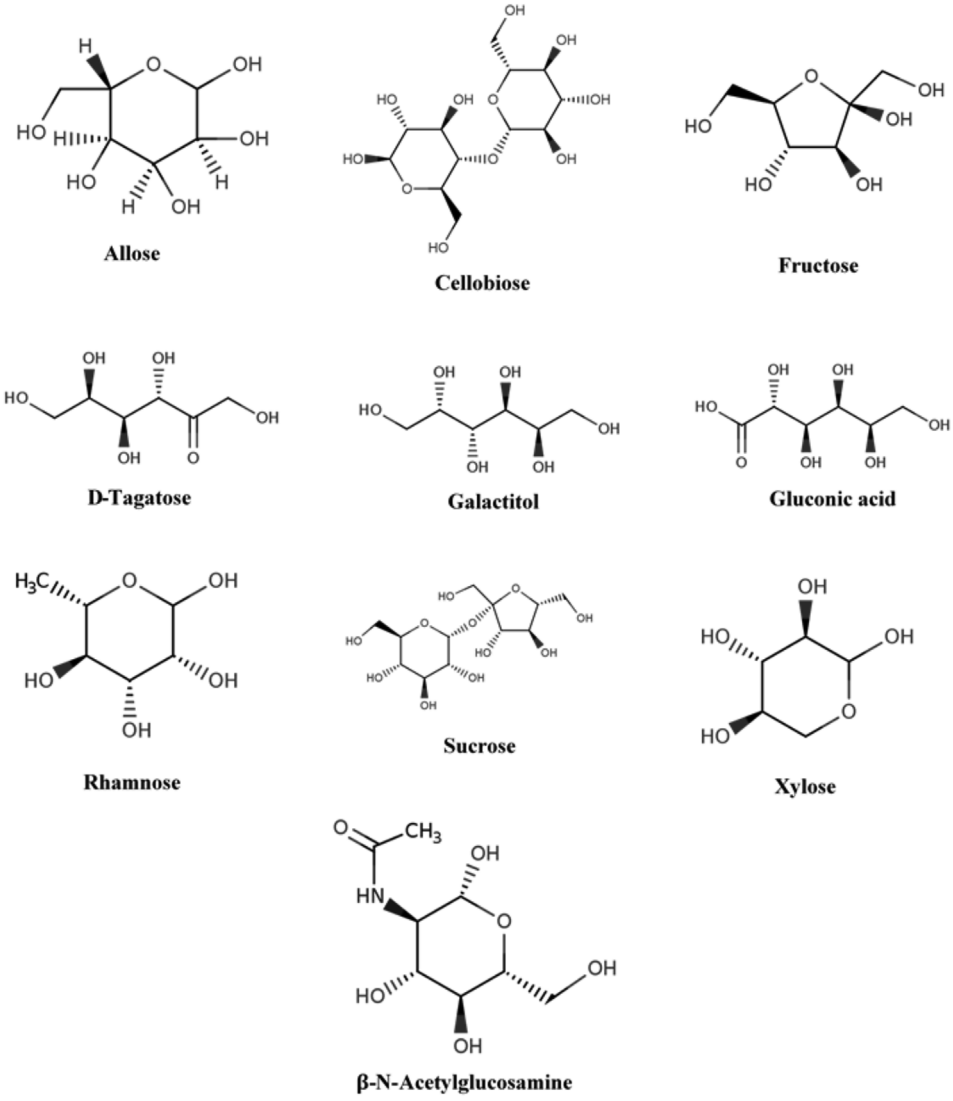


Fig. 4. ^{1}H-NMR-identified sugars in unfermented and fermentated Raffia palmwine.

Table 2
Quantitative analysis of FTIR spectroscopy of unfermented and fermented Raffia palm wine.

Unfermented (cm^{-1})	24 h Fermented (cm^{-1})	48 h Fermented (cm^{-1})	Functional Group	Chemical Bonds
3275	3260	3259	alcohols, phenols 1°, 2° amines, amides	O–H stretch, H–bonded N–H stretch
2934	2933	2935	alkanes	C–H stretch
–	–	1716	carbonyls (general) carboxylic acids aldehydes, esters, saturated aliphatic α, β–unsaturated esters	C = O stretch
1595	1591	1588.3	1° amines aromatics	N–H bend C–C stretch (in–ring)
1401	1408	1416.9	aromatics	C–C stretch (in–ring)
1250	1255	1250	alcohols, carboxylic acids, esters, ethers	C–O stretch
1037	1029	1037	aliphatic amines	C–N stretch
926	–	927	carboxylic acids alkenes	O–H bend =C–H bend
867	–	869	aromatics	C–H "oop"
–	818	818	1°, 2° amines	N–H wag
–	779	776	bend alkenes	=C–H
619	–	626	bend alkynes	–C≡C–H: C–H

samples led to significant ($p < 0.05$) decrease in intestinal glucose absorption as shown in Fig. 3A. All samples showed a dose-dependent activity, which increased with longer fermentation duration. This is seen in the decreasing IC_{50} values of the palm wine samples as the fermentation time increased, with the 48-hr fermented sample having a lowest value (0.5 μg/mL). These results showed the possibility of raffia palm wine to reduce postprandial blood glucose levels by inhibiting intestinal glucose absorption, which is consistent with its inhibitory

effect on α-glucosidase activity (Fig. 2A).

3.5. Glucose uptake activity in isolated rat psoas muscles

There was a significant ($p < 0.05$) increase of glucose uptake in muscle tissues incubated with the unfermented and 24 h fermented palm wine samples, with the latter showing the better activity as shown in Fig. 3B and Table 1. The activities were dose-dependent with increasing concentration. The 48-h showed low activity. Skeletal muscles are involved in carbohydrate metabolism and glucose homeostasis (Sinacore & Gulve, 1993). This has been attributed to GLUT-4 translocation, which stimulates glucose uptake (Satoh, 2014). Stimulation of muscle glucose uptake has been shown to be a major therapy for maintaining normoglycaemia in T2D (Pereira et al., 2017). Thus, the increased glucose uptake by the unfermented and 24 h fermented raffia palm wine samples suggested that they have anti-hyperglycemic potentials.

3.6. Proton NMR spectroscopy analysis

Although, the short-term exposure of Raffia palm wine to open air may affect its quantitative sugar profile, ^{1}H NMR analysis showed that same sugars were found in both the unfermented and fermented Raffia palm samples (Fig. 4). The sugars were: allose, cellobiose, d-tagatose, fructose, galactitol, gluconic acid, rhamnose, sucrose, xylose, and β-N-acetylglucosamine as shown in Fig. 4. The sugars included those reported as constituents of freshly tapped Raffia palm sap in previous studies (Faparusi, 1969; Eze & Ogan, 1988; Obahiagbon & Osagie, 2007). Eze and Ogan (1988) and Obahiagbon and Osagie (2007) reported the presence of sucrose, fructose, glucose and raffinose in freshly tapped Raffia palm sap, with sucrose being the major sugar constituent. The presence of maltose (Ezeagu et al., 2003), L-arabinose, D-xylose, L-rhamnose, and cellobiose (Faparusi, 1981) has also been reported as constituents of unfermented and fermented Raffia palm sap. The little or no change in the sugar quality of the fermented palm wine samples may, however, contradict previous reports by Faparusi (1969) and Obahiagbon and Osagie (2007). They reported reduced sugar levels, which was due to long-term fermentation that yielded alcohol, carbon dioxide and acetic acid. The sugars shown in Fig. 4 were not quantified and the fermentation duration was short. The antidiabetic potentials of the palm wine samples (Figs. 2A–3B) may also be due to the synergetic effects of the sugars (Fig. 4), particularly d-tagatose and rhamnose (Espinosa & Fogelfeld, 2010; Lee, Lin, & Chen, 2008). This is consistent with the reported antidiabetic properties of natural sweeteners (Chukwuma et al., 2016; Chukwuma & Islam, 2015).

3.7. Fourier Transform Infrared spectroscopy (FTIR) analysis

FTIR spectroscopy of the palm wine samples showed the presence of O–H stretch, H–bonded, N–H stretch, C–H stretch, N–H bend and C–C stretch (in-ring) bonds, suggesting the presence of alcohols, phenols, 1° and 2° amines and aromatics functional groups in all samples as shown in Suppl. 2 and Table 2. These chemical bonds show an electron-deficient moiety, suggesting that they are susceptible to accepting an electron (Erukainure et al., 2017; Harrold, 2013) and show antioxidant potential, which may be responsible for the antioxidative activity of palm wine (Fig. 1A and B). Fermentation led to the addition of the functional group, bend alkenes. The 48 h fermentation led to the addition of carbonyls (general), carboxylic acids, aldehydes, esters, saturated aliphatic and α, β–unsaturated esters functional groups as seen by the presence of C = O stretch.

4. Conclusion

These results showed the antioxidative and antidiabetic potentials of unfermented and fermented raffia palm wine, which may be due to the synergetic effect of the sugars and functional groups. The increased enzyme inhibitory activity with longer fermentation time suggested that fermentation of Raffia palm wine may increase glycemic control. However, further studies are required to validate its anti-hyperglycemic activity, *in vivo*, as well as quantify its sugar constituents. The products of fermented palm wine should also be quantified.

Conflicts of interest

The authors declare that there is no conflict of interest within this article.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fbio.2019.100423.

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