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ORIGINAL RESEARCH ARTICLE

In-vitro Inhibition of Non-fluorescent - Non-crosslinking AGEs by *Borassus aethiopum* Fruit and Leaf Fractions

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ABSTRACT

Non-enzymatic glycation is a reaction between aldehyde groups in reducing sugars and amino groups in proteins, resulting in advanced glycation end products (AGEs) formation. Increased accumulation of tissue AGEs has been linked to numerous diabetic complications. *Borassus aethiopum* (African fan palm) has been reported to have pro-apoptotic, anti-inflammatory, and antipyretic activities. This study aimed to examine the antiglycation activity of *Borrasus aethiopum* fruits and leaf fractions targeting non-fluorescent and non-crosslinking AGEs *in vitro*. Plant materials were extracted using maceration technique and then subjected to partitioning and thin-layer chromatography (TLC). Antiglycation assay was conducted using the BSA-Glucose model (using (mM) concentration) via UV-Vis detection, with aminoguanidine as the positive control. All experiments were carried out in triplicate, with data presented as mean ± standard deviation (SD), and analyzed using one-way analysis of variance (ANOVA) in SPSS version 20. The most potent fraction was characterized using attenuated total reflection-fourier transform infrared spectrometry (ATR-FTIR). Antiglycation activity revealed that the fruit chloroform fraction had the highest percentage inhibition (43% at 0 mM) compared to the leaf chloroform fraction (22%). This difference was highly significant ($p < 0.05$) compared to the control (59%). FTIR results showed the presence of functional groups such as alcohols, carboxylic acids, amines, carboximide, and nitro compounds, which have been reported to have therapeutic properties. Chloroform fractions of *Borrasus aethiopum* fruits have moderate antiglycation activity against non-fluorescent and non-crosslinking AGEs; this should be further explored to elucidate key principles for drug design and discovery.

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Antiglycation, Non-fluorescent-AGEs, *Borrasus aethiopum*, FTIR, Chromatography

INTRODUCTION

Maillard reaction, also known as nonenzymatic glycation, is the spontaneous post-translational modification of proteins or amino acids via reducing sugars; the compounds that arise from exposure to reducing sugars are known as advanced glycation end products, or AGEs (Maillard, 1912). The last stage of the Maillard reaction produces hazardous substances called advanced glycation end products (AGEs), which have complicated structures and stable chemical properties. AGEs can be produced in the human body as well as during the thermal processing of food. The accumulation of AGEs in the body, which can lead to a number of disorders, is directly related to human health (Li *et al*., 2023).

Protein-amino groups and reducing sugars combine to form advanced glycation end products (AGEs). Many free radicals, carbonyl species, and reactive dicarbonyl species are produced during the initial and propagation stages of the glycation process. Of these, methylglyoxal (MG) is the most reactive and can induce dicarbonyl stress, which can affect regular physiological processes. In the advanced stage, oxidative stress, inflammatory reactions, and chronic illnesses are thought to be caused by the synthesis of AGEs and their interaction with the receptor for AGE, known as RAGE (Yeh *et al*., 2017a).

There currently exist three widely used classification techniques for AGEs. One is to classify AGEs according to their molecular weight as either high molecular weight (HMW) or low molecular weight (LMW), albeit it's unclear where the exact boundary between LMW and HMW falls (Poulsen *et al*., 2013). According to Wu *et al*. (2011), the alternative classification approach separates products into two categories: fluorescent and crosslinking AGEs and non-fluorescent and non-crosslinking AGEs. Pentosidine, crossline, 2-(2-furoyl)-4(5)-(2-furanyl)-1 H-

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imidazole, fluorolink, glyoxal-lysine dimer (GOLD), and methylglyoxal-lysine dimer (MOLD) are examples of fluorescent and crosslinking AGEs. CML, CEL, pyrraline, argpyrimidine, 3-deoxyglucosone (3-DG), imidazolones, and methylglyoxal (MGO) imidazolones are examples of non-fluorescent, non-crosslinking AGEs. Additionally, AGEs can be categorized by dicarbonyl type, such as glyoxal (GO)-AGEs and MGO-AGEs (Eggen and Glomb, 2021). GO-AGEs include CML, N6-glycolyl lysine (GALA), glyoxal-lysine-amide (GOLA), and glyoxal-lysine-amidine (GLA); MGO-AGEs include CEL, methylglyoxal-lysine amide (MOLA), N6-lactoyl lysine, and methylglyoxal-lysine amidine (MGLA) (Ahmed *et al.*, 1997; Kasper and Schieberle, 2005; Nguyen *et al.*, 2013; Hayashi and Namiki, 2014; Zhao *et al.*, 2020).

Antiglycation has recently been recognized as a useful strategy to delay the onset of disease and human aging. To reduce the development of inflammatory reactions, glycation inhibition can limit inflammasome activation (Van Puyvelde *et al.*, 2014; Yeh *et al.*, 2017b).

Borassus aethiopum Mart. (Arecaceae) is a tropical plant species found across Africa. It is known in Nigeria as "Giginya" in Hausa, "Agbonolodu" in Yoruba, and "Ubiri" in Igbo. The dioecious plant has an average height of 20 meters and a diameter of 1 meter (Ali *et al.*, 2010). The roots, leaves, blossoms, and fruits are used for a variety of purposes, including nourishment, the treatment of cutaneous fungal infections, viral infections, including measles, and sexually transmitted diseases like herpes. There have also been reports of this plant's antipyretic properties (Sakande *et al.*, 2012; Sakande *et al.*, 2004). While the roots are used to treat asthma, the blossoms are utilized to treat impetigo (Mshana *et al.*, 2000). According to Ali *et al.* (2010), the fruit comprises sugars, provitamin A, and vitamin C. Its traditional anti-inflammatory properties are suggested by anecdotal evidence (Sakande *et al.*, 2012). According to other research, the young shoots ("muruchi") of the plant's germinating fruit have an anabolic effect on androgens, which supports the plant's local use as an aphrodisiac (Akinniyi *et al.*, 2010).

Plate 1: A picture of *Borassus aethiopum* leaves (left) and fruits (right).

To the best of the authors' knowledge, there are no reported studies on AGE inhibition by *B. gethiopum* fruits in the literature. Most research was conducted on shoots (Azubuike et al., 2019), leaves (Iornumbe et al., 2021; Usman et al., 2023), and fruit fibers (Dikmo *et al.*, 2025) extracted from *B. gethiopum*. In lieu of this, our study aimed to assess the antiglycation activity of *B. aethiopum* fruit and leaf (Plate 1)fractions targeting non-fluorescent AGEs using a UV detector, to ascertain whether Borassus aethiopum fruit and leaf fractions can inhibit non-fluorescent, non-crosslinking AGEs *in Vitro*. The objectives of the study are to determine the *in vitro* antiglycation activity of *Borassus aethiopum* fruits and leaf fractions, as well as to characterize the most active fraction using Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) Spectroscopy.

MATERIALS AND METHODS

Equipments and Reagents

Freeze dryer, mechanical grinder, blender, test tubes, test-tube rack, beakers, weighing balance, filter paper, measuring cylinder, TLC plate, UV lamp, UV-VIS, FTIR, micro pipette, spatula, DMSO, aminoguanidine, distilled water, methanol, chloroform, Hexane, ethyl acetate, phosphate buffer, D-glucose, BSA, and sodium azide.

Sample Collection

B. aethiopum leaves and fruits were collected in July, 2024 from a farm in Samaru, Kaduna State, Nigeria. Plant samples were authenticated at the Department of Botany, Faculty of Life Science, Ahmadu Bello University, Zaria, Kaduna State, Nigeria, where a voucher number (ABU01203) was deposited.

Preparation of Plant Crude Extracts

The leaves were shredded into a smaller size to allow easy drying at ambient temperature. The fruit mesocarp was peeled, sliced, and freeze-dried for 14 days. After which, the samples were pulverized separately using a Silvercrest blender and a mechanical grinder. The samples were stored for further analysis. Fifty grams (50 g) of the leaves were soaked in 500 ml methanol, while the fruit was soaked in methanol and water, respectively. Both were allowed to sit for 7 days at ambient temperature and then filtered. The filtrate was subjected to hot extraction using a water bath at 100 ^{0}C. The extract was stored using sample bottles at 4 ^{0}C.

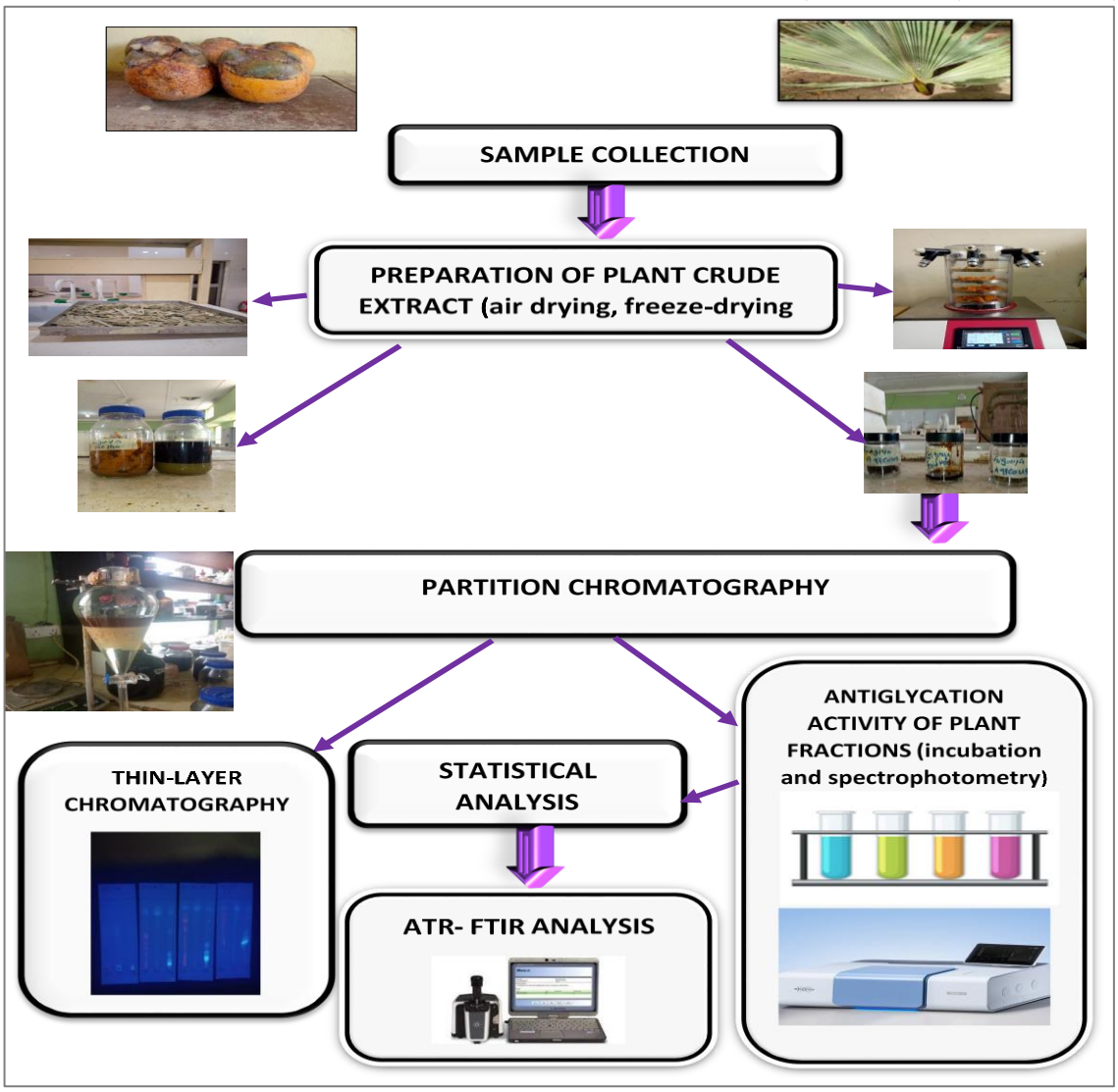

Figure 1: Flowchart of experimental workflow

Plate 2: A laboratory set up of partition chromatography

Partition Chromatography

Extracts were dissolved using distilled water. In a separation funnel, 100 mL of dissolved extract and 150 mL of chloroform were added, and the mixture was agitated. The solution was left to separate into layers; the mobile phase was decanted, and the process was repeated three times. After which the mobile phase was evaporated until a thick consistency was formed, and stored at 4^0C for further analysis (Rajbir *et al.* 2008).

Thin-Layer Chromatography (TLC)

A silica gel TLC plate was prepared with a baseline of 1.5cm and a solvent front of 7cm. The fractionated extract was dissolved in 10ml chloroform and spotted using a capillary tube. While the spot was left to dry, the mobile phase was prepared using Hexane:Ethyl acetate (H:E) in ratios of 100% Hexane, 9:1 H:E, 8:2 H:E, and 7:2 H:E. The TLC plate was assembled in the TLC chamber and allowed capillary action to occur. The plates were removed and air-dried under a fume cupboard. The plates were sprayed with p-anisaldehyde to further enhance visualization under the UV lamp.

In Vitro Antiglycation of Bovine Serum Albumin (BSA)

The antiglycation activity of plant fractions was determined using the method of Matsuura et al. (2002), Nur et al. (2019), and Abdullah et al. (2021), with slight modifications. All experiments were carried out in a clean and sterile environment. Fractions and extract were dissolved in 1ml DSMO solution and 4ml distilled water. In brief, 20 µl each of 400 µg/ml BSA and 200 mM D-glucose were added to test tubes labeled control, extract, and plant fractions (methanol and chloroform) in

triplicate. Following that, 20 µl each of 50 mM phosphate buffer (pH 7.4) containing 0.2 g/l sodium azide was added to the test tubes labeled standard and the various plant samples mentioned above. 1 mg/ml of both aminoguanidine and the plant fraction (prepared in phosphate buffer containing sodium azide) was added to test tubes labeled 'standard' and 'plant samples,' respectively. Three different concentrations (0.25 mM, 0.5 mM, and 1 mM) of the control and plant samples were prepared in triplicate. Afterward, the mixture was incubated at 37°C for 7 days. Absorbance was read at short wavelength of 254nm and long wavelength of 365nm. The percentage antiglycation activity of plant fractions and aminoguanidine was calculated using the following formula:

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

Functional group analysis using- Attenuated Total Reflection-Fourier transform infrared spectroscopy (ATR-FTIR)

The biomolecules present in the most active plant fraction were evaluated using Attenuated Total Reflection-Fourier Transform Infrared Spectroscopy (ATR-FTIR), employing a Cary 630 FT-IR Spectrometer with a DTGS detector and a platinum–ATR sampling module bearing a robust diamond crystal and a variable-angle incidence beam. Samples were analyzed directly, without treatment, to obtain ATR−FTIR spectra. Prior to measurement, the ATR crystal plate was cleaned with ethanol (96%) and dried to ensure a clean crystal surface. A small amount of the concentrated plant sample (BAFA-Cf: *B. aethiopum* fruit aqueous chloroform-fraction) was deposited directly on the diamond ATR crystal, and 125-N force was applied to provide good contact of the sample with the ATR diamond crystal by pressing against the diamond crystal using the attached pressure clamp. For sample analysis, 32 scans at 4 cm^{-1} resolution were recorded over the spectral range of 4000–650 cm^{-1}. As background, a sample-free spectrum was collected before the sample was recorded, and it was automatically subtracted from the sample spectra prior to further analysis. Each resulting spectrum was displayed on the computer screen along with its closest spectral analogue chosen from a spectral library database of standards acquired using the Cary 630 ATR-FTIR analyzer and its MicroLab FTIR software. The spectra were compared with reference spectra to identify the characteristic functional groups present in the plant sample (Ciecholewska-Jus´ko *et al.*, 2021; Derksen *et al.*, 2023; Farooq and Isma'il, 2012).

Data Analysis

All experiments were carried out in triplicate, with data presented as mean ± standard deviation (SD), and analyzed using one-way analysis of variance (ANOVA) in Statistical Package for the Social Sciences (SPSS) version 20 for Windows. A Duncan post hoc test was conducted to detect differences in the means of the various test solutions. P value less than 0.05 ($p < 0.05$) was considered statistically significant. The methodology is summarized in Figure 1.

RESULTS

Plate 2 shows the liquid-liquid partition chromatographic setup of *B. aethiopum* extracts partitioned into chloroform. Fruit and leaf fractions were developed as thin-layer chromatograms, depicted in Plate 3. The thin-layer chromatographic profiles of fruits (aqueous and methanol) and leaf extract (aqueous) partitioned in chloroform solvent, was developed using n-hexane:ethylacetate (7:3, 8:2, 9:1). TLC Spot labeled LA, FA and FM denotes spots from leaf aqueous, fruit aqueous, and fruit methanol extracts respectively.

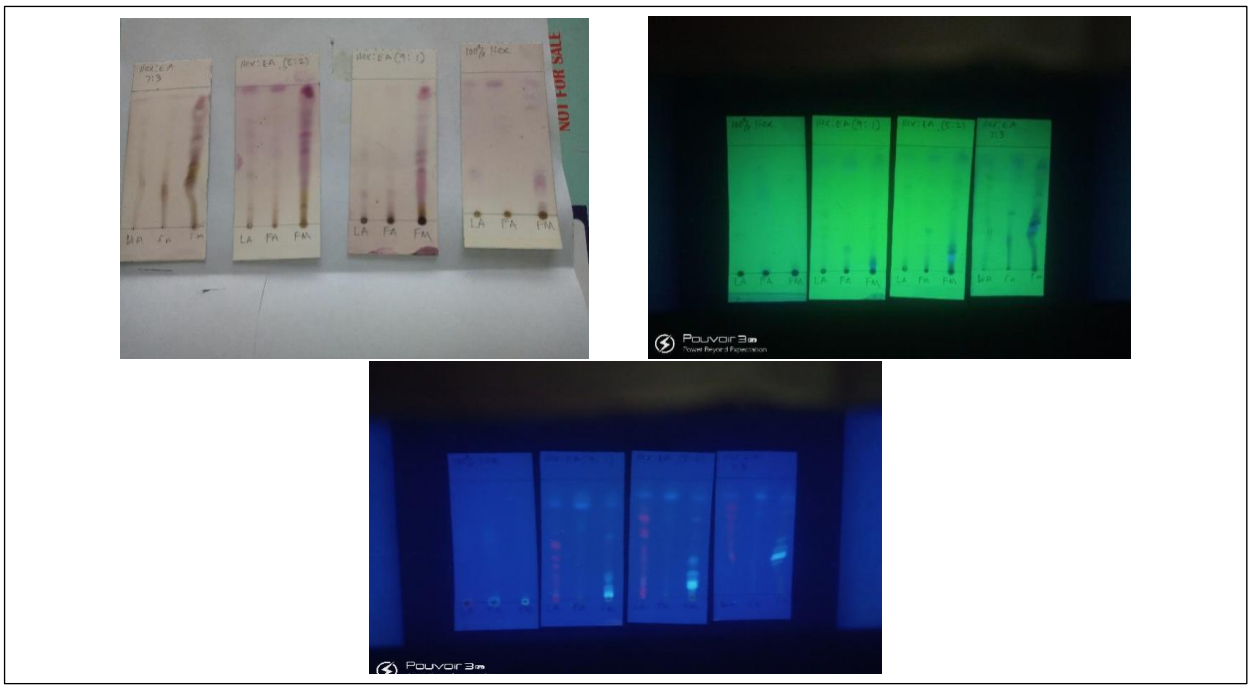

Plate 3: TLC chromatogram of *B. aethiopum* fruit and leaf fractions on precoated silica gel plate observed under *daylight* (left), *UV light at 254nm* (right) and *UV light at 365nm* (bottom)

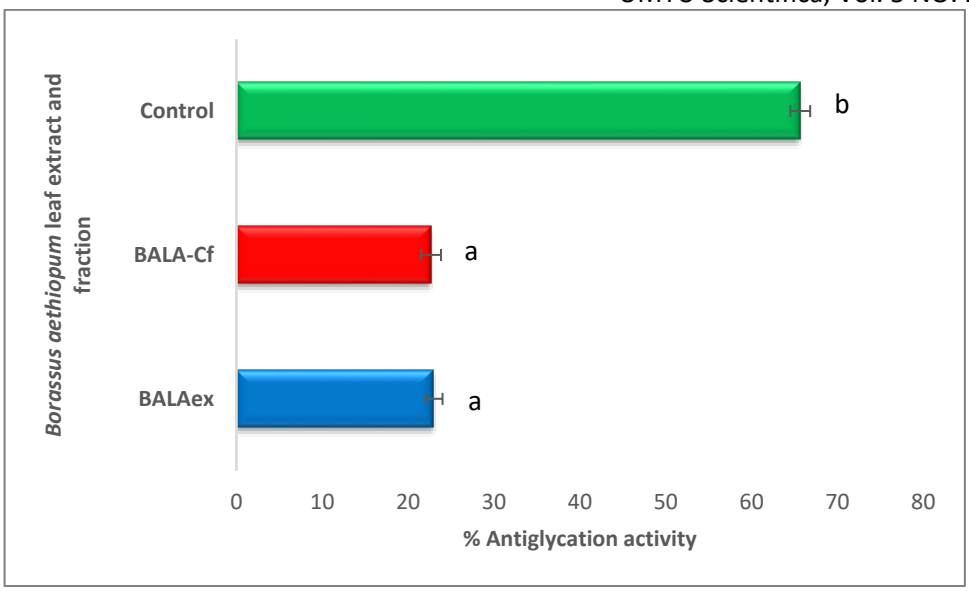

Figure 2: Antiglycation activity of *B. aethiopum* leaf extract and fraction: Data are presented as the mean ± SD of triplicate values. a-b values with different alphabets over the bars are significantly ($p < 0.05$) different from each other. All data were represented as percentage activity; BALAC-f- *B. aethiopum* leaf aqueous-chloroform-fraction, BALAex- *B. aethiopum* leaf aqueous extract.

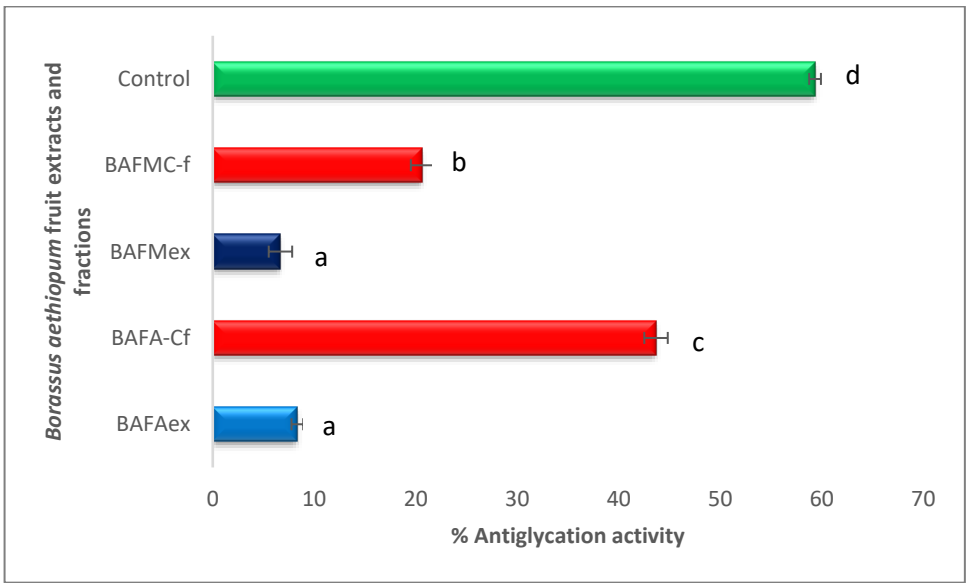

Figure 3: Antiglycation activity of *B. aethiopum* fruit extract and fractions: Data are presented as the mean ± SD of triplicate values. a-d values with different alphabets over the bars are significantly ($p < 0.05$) different from each other. All data were represented as percentage activity; BAFMC-f: *B. aethiopum* fruit methanol chloroform-fraction, BAFMex: *B. aethiopum* fruit methanol extract, BAFA-Cf: *B. aethiopum* fruit aqueous chloroform-fraction, BAFAex: *B. aethiopum* fruit aqueous extract.

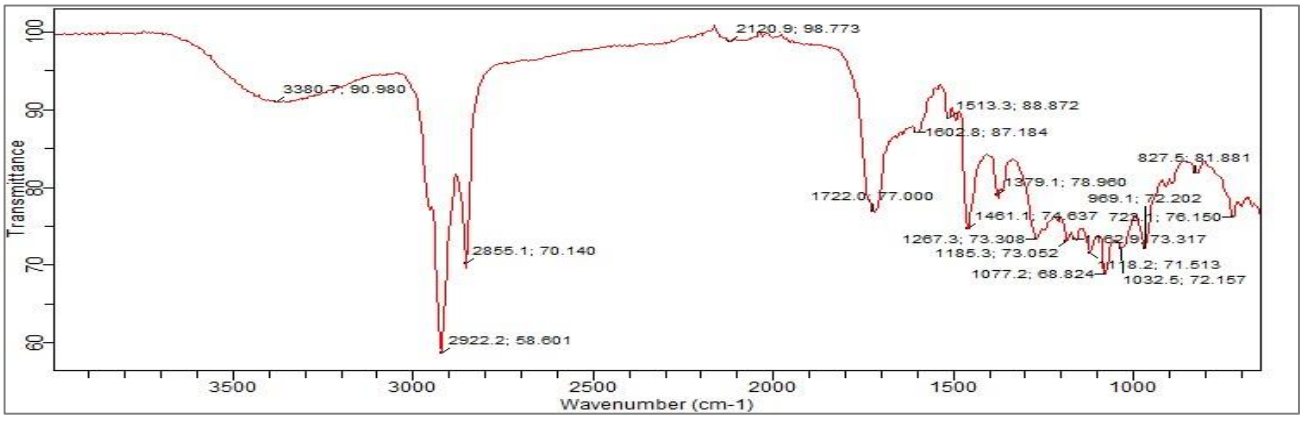

Figure 4: Fourier transformed Infrared (FTIR) spectrum of *B. aethiopum* fruit aqueous fraction identified within 4000-1500cm region.

Table 1: Functional Group Analysis of *B. aethiopum* fruit aqueous fraction from FTIR Spectra

Wave Number	Fragment	Vibration	Functional Group	Strength	Wavenumber	Reference Wavenumber
3380.7	O-H	stretching	Alcohol	S	3550-3200	Dhivya and Kalaichelvi (2017)
2922.2	C-H	stretching	Alkane	M	3000-2840	Mane and Khilare *et al.*, 2021
2855.1	C-C	stretching	Alkane	M	3000-2840	Dike *et al.*, 2023
2120.9	N=C=N	stretching	Carbodiimide	S	2145-1120	Khakhalary and Narzari, 2025
1722.0	C=O	stretching	Aliphatic ketone; cyclohexanone/ cyclopentenone	S	1725-1705	Noviany *et al.* (2023)
1602.8	C=C	stretching	Conjugated alkene	M	1650-1600	Mane and Khilare *et al.*, 2021
1513.3	N-O	stretching	Nitro compound	S	1550-1500	Corcoran *et al.*, 2012
1461.1	C-H	bending	Alkane; methylene group	M	1465-1365	Nair *et al* 2013
1379.1	O-H	bending	Carboxylic acid	M	1440-1395	Nair *et al* 2013
1267.3	C-N	stretching	Aromatic amine	S	1266-1342	Khakhalary and Narzari, 2025
1185.3	C-O	stretching	Ester	S	1210-1163	Khakhalary and Narzari, 2025
1077.2	C-O	stretching	Primary alcohol	S	1085-1050	Corcoran *et al.*, 2012
1032.5	S=O	stretching	Sulfoxide	S	1070-1030	Khakhalary and Narzari, 2025
1118.2	C-O	stretching	Vinyl ether	S	1075-1020	Noviany *et al.* (2023)
1629.73	C=C	stretching	α, β-unsaturated ketone	S	1620-1610	Noviany *et al.* (2023)
723.1	C=C	bending	Alkene; disubstituted (cis)	S	730-665	Noviany *et al.* (2023)
969.1	C=C	bending	Alkene; disubstituted (trans)	S	980-960	Noviany *et al.* (2023)
827.5	C=C	bending	Alkene; trisubstituted	M	840-790	Dhivya and Kalaichelvi (2017)

The AGE-inhibition capacity of *B. aethiopum* leaf and fruit was assessed using the BSA-Glucose model, and the results are shown in Fig. 2 and 3, respectively. For the leaves, all samples showed statistically significant ($P < 0.05$) antiglycation activity (22 and 23%) compared to the control (65%). However, the highest activity was recorded by BALAex- *B. aethiopum* leaf aqueous extract (23%); however, this activity was not significant when compared with BALAC-f- *B. aethiopum* leaf aqueous-chloroform-fraction (22%).

For *B. aethiopum* fruit samples, all samples (BAFMC-f, BAFMex, BAFA-Cf, and BAFAex) presented statistically significant ($P < 0.05$) percentage antiglycation activity (20, 6, 43, and 8%), respectively, when compared to the control (59%). However, the highest activity was recorded by BAFA-Cf: *B. aethiopum* fruit aqueous chloroform-fraction (43%); whose activity was highly significant when compared with BAFAex: *B. aethiopum* fruit aqueous extract (8%).

FTIR results obtained from characterization of the most active fraction (BAFA-Cf: *B. aethiopum* fruit aqueous chloroform-fraction) are depicted in Figure 4 and Table 1. The intense bands occurring at 3380.7 cm^{-1}, 2922.2 cm^{-1}, 2855.1 cm^{-1}, 2120.9 cm^{-1}, and 1722.0 cm^{-1}, corresponding to O-H, C-H, C-C, N=C=N, C=O stretching vibrations, indicate the presence of Alcohol, Alkane, Alkane, Carbodiimide (aliphatic ketone), and Aliphatic ketone (cyclohexanone/ cyclopentenone), respectively, in aqueous chloroform-fraction of *B. aethiopum* fruit.

Prominent peaks occurring at 1602.8 cm^{-1}, 1513.3 cm^{-1}, 1461.1 cm^{-1}, 1379.1 cm^{-1}, 1267.3 cm^{-1}, and 1185.3 cm^{-1}, corresponding to C=C, N-O, C-H, O-H, C-N, and C-O, indicate the presence of Conjugated alkene, Nitro compound, Alkane (methylene group), Carboxylic acid, Aromatic amine, and Ester in the characterized plant fraction.

Other peaks occurred at 1077.2 cm^{-1}, 1032.5 cm^{-1}, 1118.2 cm^{-1}, 1629.73 cm^{-1}, 723.1 cm^{-1}, 969.1 cm^{-1} and 827.5 cm^{-1} corresponding to C-O, S=O, C-O, C=C, C=C, C=C and C=C indicating the presence of Primary alcohol, Sulfoxide, Vinyl ether, α, β-unsaturated ketone, Alkene (disubstituted cis), Alkene (disubstituted trans) and Alkene (trisubstituted) in *B. aethiopum* fruit.

DISCUSSION

In our quest to assess the antiglycation potential of *Borassus aethiopum* fruits and leaf fractions, targeting non-fluorescent, non-crosslinking AGEs, we adopted a

methodology based on previous research on AGE (Advanced glycation end products) detection using UV techniques (Nur *et al.*, 2019; Abdullah *et al.,* 2021).

Due to paucity of data on the determination of the antiglycation capacity of plant samples targeting non-fluorescent, non-crosslinking AGEs using UV-Vis spectroscopy, our research's novelty limited our findings to a limited scope for comparison with previous research. To the best of our knowledge, there is no existing literature reporting UV-Vis detection of non-fluorescent AGEs specifically; the only citations that adopted UV-Vis methodology for the determination of AGEs in general were the studies of Nur et al., 2019, and Abdullah *et al.,* 2021, which were based on evaluating glycated-BSA in general, leveraging the hypochromicity of glycated-BSA and non-glycated BSA.

Results obtained from our study revealed the highest activity was recorded by BAFA-Cf: *B. aethiopum* fruit aqueous chloroform-fraction (43% at 0.5mM); whose activity was highly significant when compared with BAFAex: *B. aethiopum* fruit aqueous extract (8%). Moreover, the antiglycation capacity of fruit extract of *B. aethiopum* targeting non-fluorescent non-crosslinking AGEs gave a moderate activity (43% at 0.5mM) as compared to the control (aminoguanidine)-59% at 0.5mM); which was statistically significant. Moreover, the results obtained from this study indicate that BAFA-Cf (*B. aethiopum* fruit aqueous chloroform fraction) has the capacity to inhibit the formation of non-fluorescent, non-crosslinking AGEs originating from glucose, but, compared to the conventional inhibitor aminoguanidine, this activity is to a lesser extent. This implies that BAFA-Cf has a moderate non-fluorescent-non-crosslinking AGE inhibition capacity.

Our findings differ from a previous study on *B. aethiopum* leaf aqueous extracts using Spectrofluorometry, which targeted fluorescent crosslinking AGEs (Usman et al., 2023); the outcome of that study showed 96% antiglycation capacity, whereas the present study recorded 23% AGE inhibition for the leaf extract. This implies that the AGE-inhibition capacity of *B. aethiopum* leaf aqueous extract targeting non-fluorescent, non-crosslinking AGEs was significantly lower than that of the control (65%).

Functional group analysis is crucial for studying phytoconstituents, as it enables the identification of the chemical makeup of lead compounds. According to Khakhalary and Narzari (2025), FTIR analysis can identify functional groups, an essential step in characterizing chemical constituents. FTIR spectra revealed the presence of eighteen (18) peaks, each corresponding to a separate functional group. The peaks seen in the most active fraction are located within the spectral range of 3380.7, 2922.2, 2855.1, 2120.9, 1722.0, 1602.8, 1513.3, 1461.1, 1379.1, 1267.3, 1185.3, 1077.2, 1032.5, 1118.2, 1629.73, 723.1, 969.1, and 827.5 $^{cm\ -1}$. These peaks correspond to functional groups namely- alcohols, alkane, alkane, carbodiimide, aliphatic ketone (cyclohexanone/ cyclopentenone), conjugated alkene, nitro compound, alkane (methylene group), carboxylic acid, aromatic amine, ester, primary alcohol, sulfoxide, vinyl ether, α, β-unsaturated ketone, alkene; disubstituted (cis), alkene; disubstituted (trans) and alkene (trisubstituted) respectively.

The FTIR spectral analysis of *B. aethiopum* fruit chloroform-fraction exhibited a characteristic absorption band at 3380.7 and 2922.2 $^{cm-1}$, indicating the presence of phenol and carboxylic acids respectively with (O-H) group and at 1513.3 and 1118.2 $^{cm-1}$ for N-O group of Nitro and ethers respectively. The results agree with Nair et al. (2013) and Mane and Khilare et al. (2021). Also, C-H out-of-plane bending vibration for substituted benzene ring was observed at 1461.1^{cm-1}, indicating the presence of phenols and flavonoids in the plant fraction. Flavonoids are polyphenols characterized by two benzene rings joined by a linear carbon chain (Corcoran *et al.*, 2012).

The detection of hydroxyl groups suggests the presence of flavonoids, alcohols, and phenolic compounds, as noted by Kumar and Pandey (2013). The aromatic nature of *B. aethiopum* fruit chloroform-fraction is further confirmed by the presence of aromatic functional groups. Flavonoids, which contain aromatic rings and hydroxyl groups, are known for their strong antioxidant activities (Peterson *et al.,* 2005). FTIR analysis from our study revealed the presence of flavonoids, as evidenced by O-H stretching, and terpenes, as evidenced by C-H stretching, consistent with the findings of Dhivya and Kalaichelvi (2017). Peaks at 1602.8 $^{cm-1}$ in *the B. aethiopum* fruit chloroform fraction were assigned to aldehyde compounds (C=C), supporting results from Sesbania grandiflora by Noviany *et al.* (2023) and *Z. oxyphyllum* and *R. serrata* by Khakhalary and Narzari (2025).

Diverse functional groups were identified in the chloroform fraction of *B. aethiopum* fruit; this diversity, coupled with evidence for these functional groups in the past literature, may be the likely reason for the plant's antiglycation properties. Although the AGE-inhibition activity exhibited by *B. aethiopum* is moderate, it is noteworthy that the study used UV detection of AGEs in an in vitro BSA-Glucose model targeting non-fluorescent, non-crosslinking AGEs. Also, the plant sample used was a chloroform fraction partitioned from the plant's aqueous extract. It can be hypothesized that the nonpolar fraction of *B. aethiopum* fruit might have a moderate antiglycation activity as opposed to a plant fraction partitioned using a moderately polar solvent like ethyl acetate.

CONCLUSION

To the best of our knowledge, this is the first report on the determination of the antiglycation capacity of *Borrasus aethiopum* fruit and leaf fractions, targeting non-fluorescent, non-crosslinking AGEs using UV-Vis spectroscopy. Chloroform fractions of *Borrasus aethiopum* fruits had moderate antiglycation activity (43% at 0.5mM) compared to the control (aminoguanidine)-59% at 0.5mM

The results of Fourier transform infrared spectrometer (FTIR) spectra from the present study confirmed the presence of functional groups of saturated hydrocarbons

(alkanes) and unsaturated hydrocarbons (aromatic, alkenes), carbonyl, and hydroxyl group in *B. aethiopum* fruit aqueous fraction, depicting the phenolic content in the plant, which could be attributed to its antiglycation functions. It is recommended that future research be geared towards quantifying both fluorescent-crosslinking AGEs and non-fluorescent non-crosslinking AGEs to elucidate the amounts of these AGEs in a single model at a given time.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHORS' CONTRIBUTIONS

Conceptualization: HSU, ABS; Laboratory experiments: FOA, HSU; Data Analysis: FOA, HSU, SMH, MID; Writing- original draft preparation: HSU, FOA; Writing-review and editing: HSU, FAO, MID, SMH, ABS; Resources: HSU, FOA, MID, SMH, ABS; Supervision: HSU, ABS. All authors approved the final version of the manuscript.

REFERENCES

Abdullah, K. M., Arefeen, A., Shamsi, A., Alhumaydhi, F. A., & Naseem, I. (2021). Insight into the in vitro antiglycation and in vivo antidiabetic effects of thiamine: Implications of vitamin B1 in controlling diabetes. *ACS Omega, 6*(19), 12605–12614. [Crossref]

Ahmed, M. U., Frye, E. B., Degenhardt, T. P., Thorpe, S. R., & Baynes, J. W. (1997). Nε-(Carboxyethyl)lysine, a product of the chemical modification of proteins by methylglyoxal, increases with age in human lens proteins. *Biochemical Journal, 324*(2), 565–570. [Crossref]

Akinniyia, J. A., Waziri, M., & Usman, H. S. (2010). Assessment of the anabolic effect of androgens of the edible portion of the shoot of Giginya plant (*Borassus aethiopum* mart). *Journal of Scientific Research, 2*(2), 362–368. [Crossref]

Ali, A., Alhadji, D., Tchiegang, C., & Saïdou, C. (2010). Physico-chemical properties of palmyra palm (*Borassus aethiopum* Mart.) fruits from Northern Cameroon. *African Journal of Food Science, 4*(3), 115–119. [Crossref]

Azubuike, C. P., Ubani-Ukoma, U., Madu, S. J., Yomi-Faseun, O., & Yusuf, S. (2019). Characterization and application of *Borassus aethiopum* (Arecaceae) shoot pregelatinized starch as binding agent in paracetamol tablets. *Journal of Reports in Pharmaceutical Sciences, 8*(2), 172–180. [Crossref]

Ciecholewska-Juśko, D., Broda, M., Żywicka, A., Styburski, D., Sobolewski, P., Goracy, K., Migdał, P., Junka, A., & Fijałkowski, K. (2021). Potato juice, a starch industry waste, as a cost-effective medium for the biosynthesis of bacterial cellulose. *International Journal of Molecular Sciences, 22*(19), Article 10807. [Crossref]

Corcoran, M. P., McKay, D. L., & Blumberg, J. B. (2012). Flavonoid basics: Chemistry, sources, mechanisms of action, and safety. *Journal of Nutrition in Gerontology and Geriatrics, 31*(3), 176–189. [Crossref]

Derksen, G. C., Blommaert, L., Bastiaens, L., Hasşerbetçi, C., Fremouw, R., van Groenigen, J., Twijnstra, R. H., & Timmermans, K. R. (2023). ATR-FTIR spectroscopy combined with multivariate analysis as a rapid tool to infer the biochemical composition of *Ulva laetevirens* (Chlorophyta). *Frontiers in Marine Science, 10*, Article 1154461. [Crossref]

Dhivya, S. M., & Kalaichelvi, K. (2017). UV-Vis spectroscopic and FTIR analysis of *Sarcostemma brevistigma*, Wight. And Arn. *International Journal of Current Pharmaceutical Research, 9*(3), 46–49. [Crossref]

Dike, C. S., Emejulu, A. A., Chukwudoruo, C. S., Akpaki, M. A., Nsofor, W. N., & Edom, C. V. (2023). GC-MS and FTIR analyses of bioactive compounds present in ethanol leaf extract of *Sida acuta* from Imo State, Nigeria. *GSC Biological and Pharmaceutical Sciences, 25*(2), 394–404. [Crossref]

Dikmo, H. B., Ndiwe, B., Betene, A. D. O., Biwolé, A. B., Mewoli, A. E., Petrissans, A., & Segovia, C. (2025). Characterisation of a novel lignocellulosic fibre extracted from *Borassus aethiopum* Mart. fruit waste as a bio-based reinforcement. *Biomass Conversion and Biorefinery*, 1–13. [Crossref]

Eggen, M. D., & Glomb, M. A. (2021). Analysis of glyoxal- and methylglyoxal-derived advanced glycation end products during grilling of porcine meat. *Journal of Agricultural and Food Chemistry, 69*(50), 15374–15383. [Crossref]

Farooq, Z., & Ismail, A. A. (2012). *QA/QC of sugars using the Agilent Cary 630 ATR-FTIR analyzer*. Agilent Technologies, Inc. (pp. 1–6).

Hayashi, T., & Namiki, M. (1986). Role of sugar fragmentation in an early stage browning of amino-carbonyl reaction of sugar with amino acid. *Agricultural and Biological Chemistry, 50*(8), 1965–1970. [Crossref]

Hellwig, M., & Henle, T. (2012). Quantification of the Maillard reaction product 6-(2-formyl-1-pyrrolyl)-L-norleucine (formyline) in food. *European Food Research and Technology, 235*(1), 99–106. [Crossref]

Iornumbe, E. N., Sarwuan, O., & Wuana, R. A. (2021). Extraction and characterization of biosilica from *Raphia africana* fruit shells and *Borassus aethiopum* leaves. *American Journal of Applied Chemistry, 9*(5), 138–144. [Crossref]

Kasper, M., & Schieberle, P. (2005). Labeling studies on the formation pathway of Nε-carboxymethyllysine in Maillard-type reactions. *Annals of the New York Academy of Sciences, 1043*(1), 59–62. [Crossref]

Khakhalary, S., & Narzari, S. (2025). Phytochemical profiling and FTIR analysis of aqueous extracts from three selected ethnomedicinal plants of North East India. *Current Botany, 16*, 45–52. [Crossref]

Kumar, S., & Pandey, A. K. (2013). Chemistry and biological activities of flavonoids: An overview. *The Scientific World Journal, 2013*(1), Article 162750. [Crossref]

Li, L., Zhuang, Y., Zou, X., Chen, M., Cui, B., Jiao, Y., & Cheng, Y. (2023). Advanced glycation end products: A comprehensive review of their detection and occurrence in food. *Foods, 12*(11), Article 2103. [Crossref]

Maillard, L. C. (1912). Formation of melanoidins in a methodical way. *Comptes Rendus, 154*, 66–68. [Crossref]

Mane, N. B., & Khilare, C. J. (2021). Phytochemical analysis and study of functional groups by FTIR analysis of *Withania somnifera* L. Dunal. *Journal of Scientific Research, 65*(6). [Crossref]

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

Mshana, N. R. (2000). *Traditional medicine and pharmacopoeia: Contribution to the revision of ethnobotanical and floristic studies in Ghana.* Organization of African Unity/Scientific, Technical & Research Commission.

Nair, L. D., Sar, S. K., Arora, A., & Mahapatra, D. (2013). Fourier transform infrared spectroscopy analysis of few medicinal plants of Chhattisgarh, India. *Journal of Advanced Pharmacy Education & Research, 3*, 196–200. [Link]

Nguyen, H. T., Van der Fels-Klerx, H. J., & Van Boekel, M. A. J. S. (2014). Nϵ-(carboxymethyl)lysine: A review on analytical methods, formation, and occurrence in processed food, and health impact. *Food Reviews International, 30*(1), 36–52. [Crossref]

Noviany, N., Amrulloh, M. H., Mohamad, R., Irawan, B., Kusuma, W. A., Hadi, S., Supriyanto, R., Nofiani, R., Hussin, M. H., & Yuwono, S. W. (2023). FTIR-based metabolomics for characterization of antioxidant activity of different parts of *Sesbania grandiflora* plant. *Sains Malaysiana, 52*(1), 165–174. [Crossref]

Nur, M. I., Widyarti, S., & Sumitro, S. B. (2019). The study of UV spectrum in interaction astaxanthin and glycated bovine serum albumin (Gly-BSA). *Journal of Environmental Engineering and Sustainable Technology, 6*(1), 23–29. [Crossref]

Peterson, J., Dwyer, J., Bhagwat, S., Haylowitz, D., Hoiden, J., Eldridge, A. L., Beecher, G., & Aladesanmi, J. (2005). Major flavonoids in dry tea. *Journal of Food Composition and Analysis, 18*(6), 487–501. [Crossref]

Poulsen, M. W., Hedegaard, R. V., Andersen, J. M., De Courten, B., Bügel, S., Nielsen, J., Skibsted, L. H., & Dragsted, L. O. (2013). Advanced glycation endproducts in food and their effects on health. *Food and Chemical Toxicology, 60*, 10–37. [Crossref]

Rajbir Kaur RK, Saroj Arora SA, Bikram Singh BS. Antioxidant activity of the phenol rich fractions of leaves of Chukrasia tabularis A. Juss. 99(16):7692–7698. [Crossref]

Sakande, J., Nacoulma, O. G., Nikiema, J. B., Lompo, M., Bassene, E., & Guissou, I. P. (2004). Study of the antipyretic effect of *Borassus aethiopum* male inflorescences extracts. *Médecine d'Afrique Noire, 51*, 280–282.

Sakandé, J., Nikiéma, A., Kabré, E., Lompo, M., Nikiema, J. B., Nacoulma, O. G., Sawadogo, M., & Guissou, I. P. (2012). In vitro assay of potential antifungal and antibacterial activities of extracts of *Borassus aethiopum* Mart. *Biokemistri, 24*(1), 48–51. [Link]

Usman, H. S., Musa, R., Usman, M. A., Hassan, S. M., Audu, F. E., & Sallau, A. B. (2023). Effect of *Syzygium guineense* and *Borassus aethiopum* leaves on protein glycation and oxidative stress suppression. *Nigerian Journal of Basic and Applied Sciences, 31*(1), 73–79. [Crossref]

Van Puyvelde, K., Mets, T., Njemini, R., Beyer, I., & Bautmans, I. (2014). Effect of advanced glycation end product intake on inflammation and aging: A systematic review. *Nutrition Reviews, 72*(10), 638–650. [Crossref]

Wu, C. H., Huang, S. M., Lin, J. A., & Yen, G. C. (2011). Inhibition of advanced glycation endproduct formation by foodstuffs. *Food & Function, 2*(5), 224–234. [Crossref]

Yeh, W. J., Hsia, S. M., Lee, W. H., & Wu, C. H. (2017a). Polyphenols with antiglycation activity and mechanisms of action: A review of recent findings. *Journal of Food and Drug Analysis, 25*(1), 84–92. [Crossref]

Yeh, W. J., Yang, H. Y., Pai, M. H., Wu, C. H., & Chen, J. R. (2017b). Long-term administration of advanced glycation end-product stimulates the activation of NLRP3 inflammasome and sparking the development of renal injury. *The Journal of Nutritional Biochemistry, 39*, 68–76. [Crossref]

Zhao, X., Zhang, X., Ye, B., Yan, H., Zhao, Y., & Liu, L. (2020). Effect of unsaturated fatty acids on glycation product formation pathways (I) the role of oleic acid. *Food Research International, 136*, Article 109560. [Crossref]

Zhu, R., Sun, X., Zhang, Y., Yang, T., Wang, C., Zhang, J., Duan, Z., Shang, F., Fan, J., Liu, Y., Peng, X., & Chen, G. (2022). Effect of pectin oligosaccharides supplementation on infant formulas: The storage stability, formation and intestinal absorption of advanced glycation end products. *Food Chemistry, 373*, Article 131571. [Crossref]