FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 22, November, 2026, pp 339 – 344
DOI: https://doi.org/10.33003/fjs-2026-1022-5633

Phytochemical Profile and *In Vitro* α-Amylase and α-Glucosidase Inhibitory Activities of a 70 % Ethanol Extract of Green Apple (*Malus Domestica* Borkh) Fruits

[1]Anas Abba, [2]Aliyu Mas'ud Idris, [2]Abubakar Sadiq Wada, [2]Abdullahi Mustapha Huguma and [3]Azeez Babatunde Lawal

[1,2,3]Department of Pharmacognosy and Herbal Medicine, Bayero University, Kano State, Nigeria.
[2]Department of Pharmacology and Therapeutics, Bayero University Kano State, Nigeria.

*Corresponding authors' email: aabba.phd@buk.edu.ng, Phone: +2348030427519

Received: 03 Aug. 2026
Accepted: 30 Oct. 2026
Published: 04 Nov. 2026

ABSTRACT

Malus domestica belong to (Family Rosaseae) have been reported to be widely consumed as a fruit and contains diverse bioactive phytochemicals with potential health-promoting activities. This study evaluated the phytochemical profile and inhibitory properties of in vitro α-amylase and α-Glucosidase using standard procedures. The plant material was extracted with 70% ethanol and subjected to qualitative and quantitative phytochemical analysis using standard procedures. The inhibitory activities against α-amylase and α-glucosidase were evaluated at concentrations of 62.5–1000 µg/mL, using acarbose as the reference inhibitor, and IC_{50} were determined. Qualitative phytochemical screening revealed the presence of alkaloids, flavonoids, terpenoids, tannins, and glycosides. The extract had a total phenolic content of 116.699 ± 0.493 mg GAE/g extract and a total flavonoid content of 24.063 ± 0.071 mg CE/g extract. The α-amylase inhibitory activity of the extract increased from 28.989 ± 0.978% at 62.5 µg/mL to 84.201 ± 0.261% at 1000 µg/mL, compared with 88.190 ± 0.208% and 90.181 ± 0.128%, respectively, for acarbose. The IC_{50} values were 159.600 µg/mL for the extract and <62.5 µg/mL for acarbose, indicating greater α-amylase inhibitory potency of the reference inhibitor. For α-glucosidase, the extract produced inhibition values ranging from 36.758 ± 15.453% to 56.238 ± 3.932% across the tested concentration range, while acarbose produced inhibition values ranging from 46.335 ± 4.580% to 56.475 ± 2.416%. The corresponding IC_{50} values were 124.020 µg/mL for the extract and 143.715 µg/mL for acarbose. The overall 70% ethanolic extract of *M. domestica* demonstrated appreciable inhibitory activities against both carbohydrate-hydrolyzing enzymes, although its α-amylase inhibitory activity was lower than that of acarbose. These findings suggest that the observed enzyme inhibitory activities may be associated with the phenolic and other phytochemical constituents of the extract and support further investigation of *M. domestica* as a potential source of bioactive compounds with relevance to carbohydrate metabolism.

Keywords: *Malus domestica, P*hytochemicals, α-amylase, α-glucosidase, Enzyme inhibition, Phenolic compounds, Flavonoids

INTRODUCTION

Medicinal plants play an important role in healthcare delivery, particularly in developing countries where traditional medicine is widely practiced for the prevention and treatment of various ailments. The authenticity, safety, and quality of herbal drugs depend largely on the proper identification, authentication, and standardization of plant materials. In recent years, increasing attention has been directed toward natural functional foods and botanical extracts as potential sources of bioactive compounds with health promoting and therapeutic properties. *Malus domestica* Borkh commonly known as the domesticated apple, belongs to the family (Rosaceae) and is one of the most widely cultivated and commercially important fruit crops globally. Apples available in Nigerian markets are predominantly imported and include several cultivars, particularly red fleshed varieties such as Red Delicious and Gala and green fleshed varieties such as Granny Smith and Golden Delicious. Apples are recognized as important sources of bioactive secondary metabolites, including phenolic compounds, flavonoids such as quercetin, and organic acids such as chlorogenic acid (Lv, 2016). These phytochemicals have attracted considerable scientific interest because of their antioxidant, anti-inflammatory, and potential antidiabetic properties. Some of these compounds may interact with the active or regulatory sites of carbohydrate digesting enzymes, thereby reducing their catalytic property and slowing the digestion and absorption of dietary carbohydrates. Diabetes mellitus (DM) is a group of chronic metabolic disorders characterized by persistent hyperglycaemia resulting from defects in insulin secretion, insulin action, or both (American Diabetes Association, 2023). The World Health Organization classifies diabetes into four principal clinical categories: type 1 diabetes mellitus (T1DM), type 2 diabetes mellitus (T2DM), gestational diabetes mellitus (GDM), and other specific types resulting from genetic defects, pancreatic diseases, endocrine disorders, or other secondary causes (WHO, 2022). Among these, T2DM represents the most common form and is characterized by varying degrees of insulin resistance, impaired insulin secretion, and progressive deterioration of glycaemic control. Postprandial hyperglycaemia is an important component of poor glycaemic control in individuals with T2DM. In healthy individuals, the

postprandial rise in blood glucose is tightly regulated by coordinated insulin and incretin responses, whereas individuals with T2DM may experience higher and more prolonged postprandial glucose excursions (Laoufi *et al*., 2017). Repeated episodes of postprandial hyperglycaemia contribute to oxidative stress and endothelial dysfunction, thereby promoting inflammatory and pro-atherogenic processes that may accelerate vascular complications associated with diabetes (Ceriello, 2005). Persistent hyperglycaemia also promotes non enzymatic glycation of proteins and lipids, leading to the formation of advanced glycation end products (AGEs), which contribute to the development and progression of diabetic complications, including nephropathy, neuropathy, and retinopathy. One therapeutic strategy for controlling postprandial hyperglycaemia is the inhibition of carbohydrate hydrolysing enzymes, particularly α-amylase and α-glucosidase. α-Amylase initiates the hydrolysis of dietary starch into smaller oligosaccharides, while α-glucosidase catalyses the final stage of carbohydrate digestion by converting oligosaccharides and disaccharides into absorbable glucose. Inhibition of these enzymes can delay carbohydrate digestion and glucose absorption, thereby reducing the magnitude of postprandial blood glucose elevation. Although synthetic enzyme inhibitors such as acarbose are clinically useful, their use may be associated with gastrointestinal adverse effects, creating continued interest in naturally occurring alternatives from medicinal plants and functional foods. Fruits such as *Malus domestica* contain diverse phytochemicals that may contribute to their potential antidiabetic effects. Phenolic acids, flavonoids, and other antioxidant constituents present in apple tissues may influence carbohydrate metabolism through inhibition of digestive enzymes and modulation of oxidative stress. However, the phytochemical composition and biological activities of apples may vary considerably according to cultivar, geographical origin, maturity, processing, and extraction conditions. Furthermore, despite the widespread consumption and commercial availability of green apples in Nigerian markets, there is need for further investigation into their phytochemical composition and potential inhibitory effects against carbohydrate digestion processes. Therefore, the present study was designed to evaluate the phytochemical profile of 70 % ethanolic extract of green *Malus domestica*, investigate the *in vitro* inhibitory properties against α-amylase and α-glucosidase and provide scientific evidence regarding the potential of green *M. domestica* as a functional food-derived source of bioactive compounds that may contribute to the management of postprandial hyperglycaemia and serve as a basis for further pharmacological and nutritional investigations

MATERIALS AND METHODS

Collection and Authentication of Plant Materials

Fresh, fully matured green apples (*Malus domestica* Borkh.) green cultivar were purchased from Tarauni Market, Kano, Nigeria (11°58′30″N, 8°33′24″E) in November 2025. Only morphologically uniform, undamaged, green skinned fruits were selected for the study. The plant was authenticated by a plant taxonomist in the Department of Plant Science and Biotechnology, Bayero University Kano, Nigeria. A voucher specimen (BUKHAN 0403) was deposited in the herbarium for future reference.

Sample Preparation

The fruits were thoroughly washed under clean running tap water to remove adhering contaminants and subsequently rinsed with distilled water. The fruits were diced and the peel and flesh were combined and used as the study materials. The use of the whole fruit was intended to reflect the form in which apples are commonly consumed. The fruit material was sliced into thin pieces and spread on clean trays. The slices were shade dried at ambient room temperature (approximately 25–30°C) for 14 days. The dried material was pulverized using a clean mortar and pestle to obtain a homogeneous powder. The powdered material was passed through a 0.5-mm mesh sieve to obtain a relatively uniform particle size and stored in a clean, airtight plastic container protected from light and moisture until extraction.

Preparation of Extract

Three hundred grams (300 g) of the powdered *M. domestica* Borkh. fruits were accurately weighed using a digital weighing balance (Mettler Toledo, Switzerland) and transferred into a clean, stoppered conical flask. Two litres (3 L) of 70 % ethanol (v/v) were added to completely immerse the powdered materials. The flask was tightly stoppered and the mixture was macerated at room temperature for 72 h with intermittent mechanical shaking to facilitate solvent penetration and extraction of soluble constituents. Following maceration, the mixture was filtered using Whatman No. 1 filter paper to remove plant debris. The resulting filtrate was concentrated under reduced pressure using a rotary evaporator at a temperature not exceeding 45°C. The concentrated extract was collected, weighed, transferred into a clean airtight container, and stored away from light and moisture until required for analysis.

The percentage extraction yield was calculated as:

Weight of Plant Materials/Weight of Plant Extract x100

Qualitative Phytochemical Screening

The 70 % ethanol extract of green *M. domestica* Borkh. was subjected to qualitative phytochemical screening to determine the presence or absence of major classes of secondary metabolites. Standard qualitative chemical tests based on colour development and/or precipitate formation were performed according to the procedures described by Abimbola *et al.* (2013) and Trease and Evans (2002).

Determination of Total Phenolic Content

The total phenolic content (TPC) of the 70% ethanolic extract was determined using the Folin–Ciocalteu colorimetric method described by (Laoufi *et al*.,2017), with modification according to Vermerris and Nicholson (2008). The method is based on the reduction of the Folin–Ciocalteu reagent by phenolic compounds under alkaline conditions, resulting in the formation of a blue-coloured complex. Gallic acid was used as the reference standard. A series of gallic acid standard solutions was prepared and used to construct the calibration curve. The extract solution was treated under the same reaction conditions as the standards, and the absorbance was measured spectrophotometrically at the wavelength specified in the adopted procedure. The concentration of phenolic compounds in the extract was obtained by interpolation from the gallic acid calibration curve and expressed as milligrams of gallic acid equivalents per gram of extract (mg GAE/g extract). All determinations were performed in triplicate, and the results were expressed as Mean ± standard deviation (SD).

Determination of Total Flavonoid Content

The total flavonoid content (TFC) of the 70% ethanolic extract was determined using the colorimetric method described by (Laoufi *et al.,* 2017), using catechin as the reference standard. Five hundred microlitres (500 µL) of the extract solution (1 mg/mL prepared in 70 % ethanol) were

transferred into test tubes in triplicate and subjected to the same reaction procedure used for preparation of the catechin calibration standards. A series of catechin standard solutions was prepared to generate the calibration curve. The absorbance of the standards and extract samples was measured under the conditions specified in the adopted procedure. The flavonoid concentration of the extract was determined by interpolation from the catechin calibration curve and expressed as milligrams of catechin equivalents per gram of extract (mg CE/g extract).

In Vitro α-Amylase Inhibitory Activity Assay

The *in vitro* α-amylase inhibitory activity of the 70% ethanolic extract of green *M. domestica* Borkh. was evaluated using the dinitrosalicylic acid (DNSA) colorimetric method based on the procedure of Bernfeld (1955), as described by (Laoufi *et al.*, 2017). The assay was based on the ability of α-amylase to hydrolyse starch to reducing sugars. The enzyme reaction was performed in the presence and absence of different concentrations of the plant extract. Following incubation, DNSA reagent was added to develop the colour corresponding to the reducing sugars released during starch hydrolysis. The reaction mixture was subsequently treated according to the adopted procedure, and absorbance was measured at 540 nm using a spectrophotometer. Acarbose was used as the reference inhibitor. Appropriate enzyme and reagent controls were included in the assay to represent maximum enzyme activity, while extract containing controls were used where applicable to account for background absorbance.

The percentage inhibition of α-amylase activity was calculated using:

$$\text{Inhibition of } \alpha\text{-amylase activity } (\%) = [(Absc - Abs_s) / Absc] \times 100$$

Where AbsC represents the absorbance of the control (100% enzyme activity, containing enzyme and substrate but no inhibitor), and AbsS represents the absorbance of the test sample (containing enzyme, substrate, and extract or acarbose). All determinations were performed in triplicate.

In Vitro α-Glucosidase Inhibitory Activity Assay

The *in vitro* α-glucosidase inhibitory activity of the 70% ethanolic extract was determined using p-nitrophenyl-α-D-glucopyranoside (p-NPG) as the chromogenic substrate, following the method described by Laoufi *et al.* (2017) and adapted from Dahlqvist (1964). The assay was based on the hydrolysis of p-NPG by α-glucosidase to produce p-nitrophenol, which develops a measurable colour under the reaction conditions. Different concentrations of the extract were incubated with the enzyme and substrate according to the adopted procedure. Acarbose was used as the reference inhibitor. Appropriate enzyme, substrate and sample controls were included to account for enzyme activity and possible background absorbance arising from the extract. Following incubation, absorbance was measured spectrophotometrically at the wavelength specified in the adopted procedure. The percentage inhibition of α-glucosidase activity was calculated as:

$$\text{Inhibition of } \alpha\text{-glucosidase activity } (\%) = [(Absc - Abs_s) / Absc] \times 100$$

Where AbsC represents the absorbance of the 100% enzyme activity control and AbsS represents the absorbance of the test sample. All determinations were performed in triplicate.

IC_{50} Determination

The concentration dependent inhibitory activities of the extract against α-amylase and α-glucosidase were used to estimate the half maximal inhibitory concentration (IC_{50}). Percentage inhibition values were calculated from the absorbance measurements obtained at each tested concentration. Because the original experimental analysis was based on the observed inhibition values, IC_{50} was estimated by linear interpolation between the two concentrations immediately below and above 50% inhibition. The concentration corresponding to 50% inhibition was calculated from the linear relationship between these two adjacent concentrations. The same approach was applied to both α-amylase and α-glucosidase inhibition. Acarbose was similarly evaluated as the reference inhibitor. The IC_{50} values obtained by this approach were reported in µg/mL.

Statistical Analysis

All experiments were performed in triplicate, and the results were expressed as Mean ± standard deviation (SD). Descriptive statistics were used to summarize the phytochemical contents and enzyme inhibitory activities. Percentage inhibition was calculated from the absorbance values obtained for the corresponding controls and test samples. The IC_{50} values for α-amylase and α-glucosidase were estimated by linear interpolation between the concentrations immediately below and above 50% inhibition. Since the original replicate level raw data were not available for retrospective reanalysis, nonlinear dose response modelling, confidence interval estimation for IC_{50}, and additional inferential statistical analyses were not performed retrospectively.

RESULTS AND DISCUSSION

Table 1: Percentage Yield of 70 % Ethanol Extract of Green *Malus Domestica*

Plant	Weight of Dried Plant Material (g)	Weight of Dried Extract (g)	Percentage Yield (%)
Malus domestica (Green Apple)	300	46.52	15.51

Table 2: Qualitative Phytochemical Screening of the 70 % Ethanol Extract of Green Apple (*Malus Domestica* Borkh)

Metabolites	Inference
Alkaloids	+
Flavonoids	+
Tannins	+
Phenolics	+
Saponins	−
Terpenoids	+
Reducing Sugars	+

(+) = Present; (−) = Absent

Table 3: Total Phenolic and Flavonoid Content of the 70 % Ethanolic Extract of Green *Malus Domestica* Mean ± SD

TFC (mg CE/g extract)	TPC (mg GAE/g extract)
24.063±0.071	116.699±0.493

N=3

Table 4: α-Amylase Inhibitory Activity of the 70 % Ethanol Extract of Green *Malus Domestica* and Acarbose

Concentration (µg/mL)	α-amylase % Inhibition (Mean ± SD)	Acarbose % Inhibition (Mean ± SD)
62.5	28.989 ± 0.778	88.190 ± 0.208
125	43.206 ± 1.409	88.739 ± 0.711
250	67.751 ± 0.740	89.182 ± 0.626
500	78.094 ± 0.688	89.784 ± 0.328
1000	84.201 ± 0.261	90.181 ± 0.128
IC_{50} (µg/mL)	159.600	< 62.5

Table 5: α-Glucosidase Inhibitory Activity of the 70% Ethanolic Extract of Green *Malus Domestica* and Acarbose

Concentration (µg/mL)	α-glucosidase % Inhibition (Mean ± SD)	Acarbose % Inhibition (Mean ± SD)
62.5	36.758 ± 15.453	46.335 ± 4.580
125	50.211 ± 2.983	49.651 ± 2.131
250	51.614 ± 1.370	51.982 ± 1.718
500	55.413 ± 3.868	52.764 ± 1.704
1000	56.238 ± 3.932	56.475 ± 2.416
IC_{50} (µg/mL)	124.020	143.715

Table 6: Comparative IC_{50} Values of Green *Malus Domestica* Extract and Acarbose for α-Amylase and α-Glucosidase Inhibition

Enzyme	IC_{50} Green Apple Extract (µg/mL)	IC_{50} Acarbose (µg/mL)
α-Amylase	159.600	< 62.5
α-Glucosidase	124.020	143.715

Discussion

The different phytochemical constituents in the 70 % ethanol revealed the presence of alkaloids, flavonoids, tannins, phenolics, terpenoids, and reducing sugars, while saponins were absent. This phytochemical richness is consistent with previous reports on the *Malus* genus and provides a biochemical basis for the observed biological activity (Lv, 2016; *Melnic et al*., 2021). Many of these phytochemicals have been reported to possess enzyme inhibitory, antioxidant, and antihyperglycemic properties. In particular, flavonoids and phenolic compounds have been widely recognized for their ability to inhibit carbohydrate-hydrolysing enzymes through interactions with the active sites of α-amylase and α-glucosidase.

The high TPC (116.699 mg GAE/g extract) and TFC (24.063 mg CE/g extract) of the 70% ethanolic extract of green *Malus domestica* provide a compelling biochemical explanation for the significant enzyme inhibitory activity documented in this study. A well-established and extensively documented relationship exists between the phenolic and flavonoid content of plant extracts and their capacity to inhibit alpha-amylase and alpha-glucosidase (Ota and Ulrih, 2017; Laoufi *et al*., 2017). Polyphenols, particularly flavonols such as quercetin, flavan-3-ols such as catechin and epicatechin, and hydroxycinnamic acid derivatives such as chlorogenic acid, directly interact with the active sites and peripheral binding subsites of both enzymes, reducing substrate access and catalytic efficiency (Tadera *et al.,* 2006).

Quantitative phytochemical analysis further confirmed the richness of the extract in these bioactive constituents. The total phenolic content (TPC) was 116.699 ± 0.493 mg gallic acid equivalents (GAE)/g extract, while the total flavonoid content (TFC) was 24.063 ± 0.071 mg catechin equivalents (CE)/g extract. The considerably higher phenolic content suggests that phenolic compounds constitute the major class of antioxidant phytochemicals in the extract and may contribute substantially to its biological activity. Phenolic compounds are known to donate hydrogen atoms or electrons and to interact with digestive enzymes through hydrogen bonding and hydrophobic interactions, thereby reducing enzymatic activity. Likewise, flavonoids have been reported to suppress carbohydrate digestion by binding to catalytic and allosteric sites of α-amylase and α-glucosidase. The appreciable levels of these compounds therefore provide a plausible explanation for the enzyme inhibitory effects observed in this study.

The extract demonstrated concentration-dependent inhibition of α-amylase activity. Percentage inhibition increased progressively from approximately 29 % at 62.5µg/mL to approximately 84% at 1000µg/mL, indicating that inhibition increased as extract concentration increased. Although acarbose exhibited greater inhibitory activity across the concentration range, the extract showed substantial inhibition, suggesting the presence of bioactive compounds capable of reducing starch hydrolysis. Such inhibition is beneficial because slowing the breakdown of complex carbohydrates can reduce the rapid rise in postprandial blood glucose levels following meals.

Similarly, the extract exhibited marked inhibitory activity against α-glucosidase. The percentage inhibition increased with increasing concentration and, importantly, the inhibitory activity of the extract became closely comparable to that of acarbose at concentrations of 125µg/mL and above. This finding is particularly encouraging because α-glucosidase catalyses the final, rate-limiting step in intestinal carbohydrate digestion. Effective inhibition of this enzyme delays glucose absorption, thereby helping to control postprandial hyperglycaemia with potentially fewer gastrointestinal side effects than strong α-amylase inhibition.

Overall, the extract demonstrated a clear dose-response relationship against both α-amylase and α-glucosidase. The progressive increase in percentage inhibition with increasing extract concentration confirms that the observed effects were concentration dependent rather than incidental. Such predictable dose-dependent behaviour is characteristic of genuine enzyme–inhibitor interactions and supports the pharmacological potential of the extract.

The calculated IC_{50} values further quantified the inhibitory potency of the extract. The IC_{50} was 159.600µg/mL for α-amylase and 124.020µg/mL for α-glucosidase, both of which fall within the sub-milligram per millilitre range generally considered indicative of meaningful enzyme inhibitory activity for natural products Lasraj *et al.* (2022). These findings demonstrate that the extract possesses appreciable inhibitory activity against both carbohydrate-digesting enzymes and support its potential use as a natural source of antidiabetic agents.

Comparison of the IC_{50} values with those of the standard drug acarbose showed differing patterns of inhibition between the two enzymes. For α-amylase, acarbose remained the more potent inhibitor, with an IC_{50} of less than 62.5µg/mL, compared with 159.600 µg/mL for the extract. However, for α-glucosidase, the extract exhibited an IC_{50} of 124.020 µg/mL, compared with 143.715µg/mL for acarbose under the same experimental conditions, indicating closely comparable inhibitory activity. It should be noted, however, that the IC_{50} value of the extract for α-glucosidase was derived partly from the 62.5µg/mL data point, which exhibited relatively high variability. Consequently, this estimate should be interpreted with appropriate caution. Nevertheless, the consistently high percentage inhibition observed at concentrations of 125µg/mL and above provides stronger evidence that the extract possesses substantial α-glucosidase inhibitory activity this might be as a results of variation in cultivars, extraction processes i.e solvent/ratio used, assay conditions, use of whole fruits not the peels as prescribed by (Prasad *et al.*, 2026).

Conclusion

The 70% ethanol extract of *Malus domestica* contained several bioactive phytochemicals such as phenolic constituents. Collectively or individually, the 70% ethanolic extract of green *Malus domestica* possesses significant *in vitro* antidiabetic potential through the inhibition of carbohydrate-hydrolysing enzymes, this supports its potential as a natural source of bioactive compounds that may contribute to the management of postprandial hyperglycaemia and provide a scientific basis for its ethnomedicinal uses despite all the limitations of the work such as only *in vitro* study, single extract, basic IC_{50} assay among others.

Funding Acknowledgement

Authors gratefully acknowledged the sponsorship of this research by the Tertiary Education Trust Fund (TETFund), Nigeria, through the Institutional Based Research (IBR) intervention which made the preparation of this manuscript possible. The authors also appreciate the management of Bayero University Kano for providing the enabling environment and institutional support required for this study. All points expressed in this manuscript are from the authors of this manuscript not necessarily reflect the official position of TETFund.

REFERENCES

Abimbola, A. M., Baba, I. A., Yenusa, E. Z., Omanibe, S. J & Oladimeji, I. H (2013). Anti-trypanosomal effect of Peristrophe bicalyculata extract on *Trypanosoma brucei* brucei-infected rats. *Asian Pacific Journal of Tropical Biomedicne*. 3: 523-531.

American Diabetes Association. (2023). Standards of medical care in diabetes—2023. Care, 46 (Suppl. 1), S1–S291. https://doi.org/10.2337/dc23-Sint

Bernfeld, P. (1955). Amylases, alpha and beta. Methods in Enzymology, 1, 149–158. https://doi.org/10.1016/0076-6879(55)01021-5

Ceriello, A. (2005). Postprandial hyperglycemia and diabetes complications: Is it time to treat? Diabetes, 54(1), 1–7. https://doi.org/10.2337/diabetes.54.1.1

Laoufi, H., Benariba, N., Adjdir, S., & Djaziri, R. (2017). *In vitro* α-amylase and α-glucosidase inhibitory activity of Ononis angustissima extracts. *Journal of Applied Pharmaceutical Science,* 7(2), 189–195. https://www.japsonline.com/admin/php/uploads/2171_pdf.pdf

Lasraj, N., Buhrim, M., & Kharchoufa, L. (2022). Phytochemical analysis, α-glucosidase and α-amylase inhibitory activities and acute toxicity studies of extracts from pomegranate (*Punica granatum*) bark. *Foods,* 11(9), Article 1353. https://doi.org/10.3390/foods11091353

Lv, Y. (2016). Triterpenes and phenolic compounds in Apple fruit (*Malus domestica* Borkh.) [Doctoral dissertation, Swedish University of Agricultural Sciences]. Epsilon Open Archive. https://pub.epsilon.slu.se/13001/1/Lv_Y_160128.pdf

Melnic, V., Bunea, A., Chira, R. I., Bunea, C. I., Socaci, S., & Mitre, V. (2021). Phytochemical content and antioxidant activity of Malus domestica Borkh peel extracts. *Molecules*, 26(24), Article 7636. https://doi.org/10.3390/molecules26247636

Monnier, L., Mas, E., Ginet, C., Michel, F., Villon, L., Cristol, J. P., & Colette, C. (2007). Activation of oxidative stress by acute glucose fluctuations compared with sustained chronic hyperglycemia in patients with type 2 diabetes. *JAMA*, 295(14), 1681–1687. https://doi.org/10.1001/jama.295.14.1681

Ota, A., & Ulrih, N. P. (2017). An overview of herbal products and secondary metabolites used for management of type two diabetes. *Frontiers in Pharmacology*, 8, Article 436. https://doi.org/10.3389/fphar.2017.00436

Prasad, R.C., Umeza, B.Y.. Afzal Khan, A.K., Nayaka, S.R., & Jayaraman, T. (2026). In vitro Antioxidant and Antiglycemic Effects of *Malus domestica, Musa acuminata Colla, Mangifera indica, Citrus reticulata and Punica granatum* Fruits Peel Extracts. *International Journal* of *Pharmaceutical Investigation*. 16 (2):702-7.

Tadera, K., Minami, Y., Takamatsu, K & Matsuoka. T. (2006). Inhibition of alpha-glucosidase and alpha-amylase by flavonoids. *Journal of Nutritional Science and Vitaminology* 52(2):149-53. https://doi.org/10.3177/jnsv.52.149

Vermerris, W., & Nicholson, R. (2008). Isolation and identification of phenolic compounds. In *Phenolic compound biochemistry* (pp. 151–196). *Springer*. https://doi.org/10.1007/978-1-4020-5164-7_5

World Health Organization. (2022). *Global report on diabetes*. WHO. https://www.who.int/publications/i/item/9789240015128

©2026 This is an Open Access article distributed under the terms of the Creative Commons Attribution 4.0 International license viewed via https://creativecommons.org/licenses/by/4.0/ which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is cited appropriately.