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Original Article

DICHLOROMETHANE EXTRACT OF THE LEAVES OF *ARBUTUS PAVARII* PAMP. EXHIBITS CYTOTOXICITY AGAINST THE PROSTATE CANCER CELL LINE PC3: A BIOASSAY-GUIDED ISOLATION AND IDENTIFICATION OF ARBUTIN AND BETULINIC ACID METHYL ESTER

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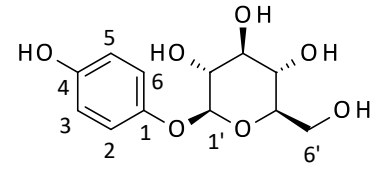
Abstract

Background: *Arbutus pavarii* Pamp. (fam. Ericaceae), commonly known as "Shmeri", "Shmar" and "Libyan Strawberry", is an endemic Libyan medicinal plant, growing almost exclusively in the Al-Jabel Al-Akhdar mountainous region in Libya.
Aims: To assess the cytotoxicity of *A. pavarii* against human cancer cell lines and to carry out bioassay-guided isolation and identification of compounds.
Materials and Methods: Shed-dried and ground leaves of *A. pavarii* were Soxhlet-extracted, successively, with *n*-hexane, dichloromethane (DCM) and methanol (MeOH), and assessed for cytotoxicity against several human cancer cell lines using the MTT assay. The cytotoxicity of the DCM extract against the normal human prostate cell line PNT2 was also assessed to determine the selectivity index (SI). The DCM extract was subjected to vacuum liquid chromatography (VLC) to produce eight fractions. A reversed-phase preparative HPLC analysis of the active VLC fraction was carried out to purify the major compounds present in the active fraction, and the structures of the compounds were elucidated by spectroscopic means.
Results: The DCM extract was more cytotoxic against the PC3 cell line (IC_{50}= 26 μg/mL) but less toxic to the normal human prostate cell line PNT2 (IC_{50} = 90 μg/mL) with a selectivity index of 3.5. VLC analysis produced 8 fractions, with fraction VLC-5 most active against PC3 cells. Prep-HPLC-based purification of VLC-5 afforded the isolation of arbutin (**1**) and betulinic acid methyl ester (**2**), the structures of which were elucidated by spectroscopic means.
Conclusion: The DCM extract of the leaves of *A. pavarii* exhibited significant cytotoxicity to PC3 cells, but much less cytotoxicity against normal human prostate cell line. The isolated compounds from the active fraction, arbutin (**1**) and betulinic acid methyl ester (**2**), which were previously shown to possess cytotoxic properties, could be responsible for the cytotoxicity of the DCM extract.

INTRODUCTION

Arbutus pavarii Pamp. (fam: Ericaceae), commonly known as “Shmeri”, “Shmar” and “Libyan Strawberry”, is an endemic Libyan medicinal plant (Kabiel et al., 2016; Nahar et al., 2021). This evergreen shrub grows almost exclusively in the Al-Jabel Al-Akhdar mountainous region in Libya. It is a forage species of plant for honeybees to produce a specific type of honey and has long been a component of Libyan traditional medicinal preparations for the treatment of both gastritis and kidney diseases (El Hawary et al., 2016). The berries of this plant are rich in minerals, nutrients, carbohydrates and ascorbic acid, and the aerial parts have their application in the tanning process (Alsabri et al., 2013). Previous phytochemical investigations performed on this species revealed the presence of simple phenolic compounds like arbutin (**1**) and gallic acid, and flavonoids and tannins, e.g., apigenin, epicatechin, hesperidin, kaempferol, naringin, quercetin and rutin, as well as some triterpenes and sterols (Alsabri et al., 2013; Asheg et al., 2014; El Hawary et al., 2016; Kabiel et al., 2016; Buzgaia et al., 2020). Rutin and arbutin (**1**) are the most abundant compounds in the aerial parts of this plant, and arbutin (**1**) is considered as a chemotaxonomic marker for the genus *Arbutus* L (Asheg et al., 2014; El Hawary et al., 2016; Buzgaia et al., 2020). Only a few published reports on the bioactivities of this species described preliminary antioxidant, antimicrobial and cytotoxic activities of the crude extracts (Hussain and Tobji, 1997; Hasan et al., 2011; Alsabri et al., 2013; El Hawary et al., 2016; Kabiel et al., 2016). However, reports on bioassay-guided isolation of active compounds, and their subsequent assessment for bioactivity are limited. We now report, for the first time, on the assessment of cytotoxicity of the dichloromethane (DCM) extract against several human cancer cell lines, and a bioassay-guided isolation and spectroscopic identification of the major compounds, arbutin (**1**) and betulinic acid methyl ester (**2**) (Figure 1), from the DCM extract of the leaves of *A. pavarii*.



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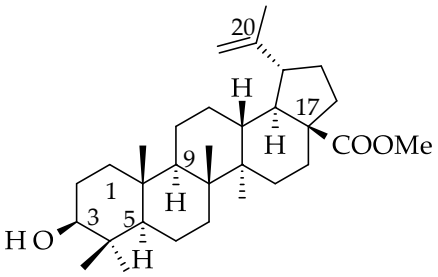

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Figure 1: Structures of arbutin (**1**) and betulinic acid methyl ester (**2**)

MATERIALS AND METHODS

General Experimental Procedure

1D and 2D NMR spectroscopic analyses were carried out on a Bruker 600 MHz AMX Ultrashield NMR spectrometer using the deuterium locking. Chemical shifts are in d ppm and coupling constants *J* in Hz. Vacuum liquid chromatography (VLC) was performed on silica gel 60H (Sigma-Aldrich, UK) column under vacuum. Solvents for extraction and chromatographic work were of analytical grade, obtained from Fisher Scientific, UK, and used without further purification.

Plant Materials

The leaves of *Arbutus pavarii* Pamp. (fam. Ericaceae) (Figure 2) were collected from the Al-Jabal Al-Akhdar region in Libya (latitude and longitude: 32° 35' 51" North and 21° 28' 22" East) in 2016, and a voucher specimen for this collection (D6854201) has been retained at the Herbarium of the Faculty of Science, Tripoli University, Libya. Shed-dried leaves were ground to a fine powder using a coffee grinder.

Figure 2. *Arbutus pavarii* shrub

Extraction

A portion (150 g) of the dried ground leaves was Soxhlet-extracted, sequentially, with *n*-hexane, dichloromethane (DCM) and methanol (MeOH), 900 mL each and 10 cycles each solvent. All extracts were filtered using a Whatman filter paper, evaporated to dryness using a rotary evaporator (Cole-Parmer, UK) and stored at 4^{o}C.

Vacuum Liquid Chromatography (VLC)

VLC was carried out following the method described by Sarker and Nahar (2012). The DCM extract (2.4 g) was subjected to VLC fractionation on a silica 60H column under vacuum using a step gradient comprising *n*-hexane, ethyl acetate (EtOAc) and MeOH of different proportions and in the order of increasing polarity, e.g., 100% *n*-hexane, 10, 30, 50, 80% EtOAc in *n*-hexane, 100% EtOAc and 50% MeOH in EtOAc.

Isolation of Compounds by Preparative High Performance Liquid Chromatography (prep-HPLC)

Prep-HPLC separation was performed on an Agilent 1200 preparative HPLC comprising a binary gradient pump, photodiode array detector and a computer with control and data analysis software. In the preparative isolation of compounds, an ACE prep-column [150 × 21.2 mm, 5 μm, Hichrom Ltd, UK; MeOH-water linear gradient: 50-100% acetonitrile in water (both containing 0.1% 0.1% trifluoro acetic acid, TFA) in 30 min, then 100% acetonitrile for 10 min, flow rate: 10 mL/min, monitored simultaneously at 215, 254, 280 and 320 nm] was used with a volume of injection of 200 μL.

Identification of Compounds

The identity of the isolated compounds (**1** and **2**) (Figure 1) was confirmed by spectroscopic means, particularly, by MS and 1D and 2D NMR data analyses.

Cytotoxicity Assay (MTT Assay)

Human cancer cell lines A549 (human lung carcinoma), EJ138 (human bladder carcinoma), HepG2 (human liver hepatocellular carcinoma), MCF7 (human breast adenocarcinoma) and PC3 (human prostate cancer) were used in this study. Additionally, the normal human prostate cell line PNT2 was used. These cell lines were obtained from the European Collection of Authenticated Cell Cultures. All cell lines were adherent epithelial cells derived from human carcinoma or adenocarcinoma. Cytotoxicity of the extracts of *A. pavarii* was investigated at the following concentrations 0.0, 0.005, 0.01, 0.05, 0.1 and 0.5 mg/mL for 24 hours then toxicity assessed using the MTT assay, Mosmann, 1983; Evans, 2003). The VLC fractions were assessed for cytotoxicity using the same assay but at different concentrations: 0.0, 0.0004, 0.002, 0.01, 0.05 and 0.25 mg/mL. The IC_{50} values of these extracts against the tested cell lines (where appropriate), and that of the VLC fractions against the PC3 cell line were calculated applying the method described by

Patel *et al.* (2009). Any IC_{50} value of greater than 100 µg/mL was considered non-cytotoxic. The cytotoxicity of the *n*-hexane extract could not be assessed because of its insolubility in DMSO.

RESULTS

The Soxhlet extraction of the shed-dried ground leaves of *A. pavarii* afforded three different extracts, *i.e.,* *n*-hexane, DCM ad MeOH, with 4.4, 1.8 and 36.0% yields, respectively. Because of insolubility issues, *n*-hexane extract was not subjected to cytotoxicity assay (MTT assay), but the other two extracts were assessed for their cytotoxicity against five different human cancer cell lines, and the DCM extract was found to be the most cytotoxic extract (Table 1). Additionally, the DCM extract was tested for cytotoxicity against the normal human prostate cell line PNT2 (Table 1), and the selectivity index (SI), which is the ratio between the IC_{50} values against the normal cells and the cancerous cells, was calculated.

Table 1. Cytotoxicity of DCM extract of *A. pavarii* against five human cancer cell lines and normal human prostate cell line PNT2

Cancer cell lines	Inhibitory concentration 50% (IC_{50}) in µg/mL
A549 (human lung carcinoma)	>100
EJ138 (human bladder carcinoma)	90
HepG2 (human liver hepatocellular carcinoma)	>100
MCF7 (human breast adenocarcinoma)	>100
PC3 (human prostate cancer)	26
PNT2 (normal human prostate cells)	90

As the DCM extract was significantly cytotoxic, and it showed the most prominent activity against the PC3 cell line, it was subjected to VLC fractionation resulting in eight different fractions (VLC-1 to VLC-8), which were then assessed for cytotoxicity against the PC3 cell line (Table 2)

The most active fraction (VLC-5) was subjected to reversed-phase preparative HPLC on a C_{18} preparative column using a linear gradient elution with a mobile phase comprising acetonitrile and water (both containing 0.1% TFA). Preparative HPLC analysis of a portion of the fraction VLC-5 resulted in the isolation of two major compounds **1** and **2** (Table 3), which were identified as arbutin (**1**) and betulinic acid methyl ester (**2**) by spectroscopic analyses, especially, MS, and 1D and 2D NMR, as well as by comparison with published data for these compounds (Huo et al., 2012; Avelino-Flores et al., 2015; Das et al., 2015; Mishra et al., 2016; Deans et al., 2018).

Table 2. VLC fractions of the DCM extract of *A. pavarii* and their cytotoxicity against the PC3 cell line

VLC fractions	Mobile phase composition	Weight (mg)	IC_{50} value in µg/mL
VLC-1	100% *n*-Hexane	150	>100
VLC-2	10% EtOAc in *n*-hexane	65.2	>100
VLC-3	30% EtOAc in *n*-hexane	41.7	>100
VLC-4	50% EtOAc in *n*-hexane	165.7	40
VLC-5	50% EtOAc in *n*-hexane	477.0	30
VLC-6	80% EtOAc in *n*-hexane	117.0	98
VLC-7	100% EtOAc	130.8	>100
VLC-8	50% MeOH in EtOAc	97.1	>100

Table 3. Isolation and identification of arbutin (1) and betulinic acid methyl ester (2) by prep-HPLC from the fraction VLC-5 of the DCM extract of *A. pavarii* (retention time and weight)

Compounds	Retention time (t_R) in min*	Weight in mg
Arbutin (1)	17.2	2.6
Betulinic acid methyl ester (2)	32.1	2.2

Arbutin (**1**): White powder; UV (MeOH) l_{max}: 212 and 282 nm; ESMS *m/z*: 273 $[M+H]^+$; ^{1}H NMR (600 MHz, in CD_3OD): δ 6.77 d (*J* = 8.9 Hz, H-2 and H-6), 6.97 d (*J* = 8.9 Hz, H-3 and H-5), 4.81 d (*J* = 7.6, H-1'), 3.50-3.91 (overlapped peaks, H-2', H-3', H-4', H-5' and H_2-6'); ^{13}C NMR (150 MHz, in CD_3OD): δ 151.8 (C-1 and C-4), 118.8 (C-2 and C-6), 116.3 (C-3 and C-5), 103.2 (C-1'), 77.5 (C-3'), 77.0 (C-5'), 75.1 (C-2'), 71.5 (C-4') and 62.7 (C-6') (Avelino-Flores et al., 2015; Das et al., 2015; Deans et al., 2018).

Betulinic acid methyl ester (**2**): White amorphous powder; UV (MeOH) l_{max}: 208 nm; ESMS *m/z*: 493 $[M+Na]^+$; ^{1}H NMR (600 MHz, in CD_3OD): δ 4.77 bs and 4.64 bs (H_2-29), 3.52 s (-OCO**Me**) 3.22 dd (*J* = 4.6 and 11.4 Hz, H-3), 3.10 m (H-19), 1.51 t (*J* = 3.6, H_2-1), 1.80 m (H_2-2), 1.70 s (H_3-30), 0.98 s (H_3-27), 0.94 s (H_3-26), 0.87 s (H_3-25), 0.86 (H_3-24) and 0.84 (H_3-23); ^{13}C NMR (150 MHz, in CD_3OD): δ 178.8 (C-28), 151.0 (C-20), 110.0 (C-29), 78.4 (C-3), 56.6 (C-17), 55.7 (C-5), 51.0 (C-9), 50.0 (-OCO**Me**), 49.0 (C-19), 47.4 (C-18), 42.8 (C-14), 41.0 (C-8), 39.5 (C-4), 39.2 (C-1), 38.6 (C-13), 37.5 (C-22), 37.2 (C-10), 34.8 (C-7), 32.2 (C-16), 31.0 (C-21), 30.0 (C-15), 28.6 (C-23), 28.1 (C-2), 25.9 (C-12), 21.0 (C-11), 19.5 (C-30), 19.2 (C-20), 18.9 (C-6), 16.9 (C-26), 16.3 (C-24), 16.2 (C-25) and 15.0 (C-27) (Huo et al., 2012; Mishra et al., 2016).

DISCUSSION

The highest extraction yield was obtained by MeOH (36 %), which could be due to the presence of copious amounts of polar phenolic and polyphenolic compounds (e.g., tannins) and their glycosides in the leaves. On the other hand, DCM produced the least extraction yield (1.8%), which is not surprising, as most nonpolar compounds are generally extracted by *n*-hexane and the polar compounds by MeOH, leaving DCM to extract only some compounds of medium polarity, and a few left over or trailing nonpolar compounds from the *n*-hexane extract and a small proportion of polar compounds that are fully extracted in the MeOH extract.

In the MTT assay, the DCM extract showed significant cytotoxicity against the prostate cancer cell line PC3 (IC_{50} = 26 μg/mL), and a moderate level of activity against the bladder cancer cell line EJ138 (IC_{50} = 90 μg/mL) (Table 1). However, this extract did not show any cytotoxicity against three other cancer cell lines: HepG2, A459 and MCF7. Moreover, the cytotoxicity of the DCM extract against normal human prostate cell line PNT2 (IC_{50} = 90 μg/mL) (Table 1) was much less than its activity against the prostate cancer cell line PC3. The selectivity index (SI) of the DCM extract was determined as 90/26 = 3.5, indicating its selective cytotoxicity toward cancer cells as opposed to normal cells. The MTT result also demonstrated that the cytotoxicity of the DCM extract was selective to certain cancer cells and was not cytotoxic to each cell line tested.

As the DCM extract was most active against the PC3 cell line, this cell line was chosen for further bioassay-guided isolation processes, which started with the VLC fractionation of the DCM extract resulting in eight different fractions of different weights (Table 2). Fraction eluted with 50% EtOAc in *n*-hexane (VLC-5) was the highest yielding fraction (477 mg), followed by VLC-4 (165.7 mg), VLC-1 (150.0 mg) and so on (Table 2). The overall recovery of materials from the VLC process was 51.8%, which is quite usual in such operations (Sarker and Nahar, 2012). All eight fractions were subjected to the MTT assay using the PC3 cell line, and VLC-5 produced the most prominent cytotoxic effect against this cell line (IC_{50} = 30 μg/mL) (Table 2). Therefore, this fraction was chosen for prep-HPLC analysis aiming at isolating major compounds from this fraction. Fractions VLC-1, VLC-2, VLC-3, VLC-7 and VLC-8 were inactive against this cell line, while fractions VLC-4 and VLC-6, in addition to VLC-5, showed cytotoxicity with IC_{50} values of 40 and 98 μg/mL. As VLC-5 was the most active fraction, it was subjected to prep-HPLC analysis resulting in the purification of two compounds which were identified as arbutin (**1**) and betulinic acid methyl ester (**2**) by

spectroscopic means (Huo et al., 2012; Avelino-Flores et al., 2015; Das et al., 2015; Mishra et al., 2016; Deans et al., 2018).

Compound **1** was eluted first (t_R = 17.2 min) in the prep-HPLC run and obtained as a white powder. While the UV absorption maxima of this compound were 212 and 282 nm, the ESIMS analysis revealed the pseudomolecular ion $[M+H]^+$ at *m/z* suggesting the molecular formula $C_{12}H_{16}O_7$. Analyses of the ^{1}H NMR and the ^{13}C NMR spectra of compound **1** revealed signals assignable to the protons/carbons of a *para*-di-substituted aromatic ring at δ_H 6.97 (d, *J* = 8.9 Hz, 2H) and δ_C 116.3, and δ_H 6.77 (d, *J* = 8.9 Hz, 2H) and δ_C 118.8 and all required signals for a b-D-glucopyranoside unit (data shown in the Results section). While a ^{1}H-^{1}H COSY spectrum showed all ^{1}H-^{1}H scaler couplings, a ^{1}H-^{13}C HMBC displayed all major ^{1}H-^{13}C long-range correlations and helped identification of this compound as arbutin (**1**) (Figure 1). The most noteworthy HMBC correlation was the ^3J correlation from the glucose anomeric proton (δ_H 4.81) to the C-1 (δ_C 103.2) of the aromatic ring. All data were comparable to the published data for arbutin (**1**) (Avelino-Flores et al., 2015; Das et al., 2015; Deans et al., 2018).

Compound **2** was eluted beyond the gradient run duration and during the cleaning phase (t_R = 32.1 min) in the prep-HPLC run, and obtained as a white amorphous powder, having a low UV absorbance maximum at 208 nm. The ESIMS exhibited the sodiated molecular ion peak at *m/z* at 493 $[M+Na]^+$ corresponding to the molecular formula $C_{31}H_{50}O_3$. The ^{1}H and ^{13}C NMR spectra showed characteristic signals for a betulinic acid skeleton with an additional methyl ester functionality (Huo et al., 2012; Mishra et al., 2016), including the signals for six methyl groups (δ_H 1.70, 0.98, 0.94, 0.87, 0.86 and 0.84; δ_C 28.6, 19.5, 16.9, 16.3, 16.2 and 15.0), a hydroxyl group (δ_H 3.22; δ_C 78.4), an olefinic methylene functionality (δ_H 4.77 bs and 4.64; δ_C 151.0) and a methyl ester group (δ_H 3.52; δ_C 178.8 and 50.0). Thus, the compound was identified as betulinic acid methyl ester (**2**), and all data were comparable to the literature data for this compound (Huo et al., 2012; Mishra et al., 2016).

This is the first report on the assessment of cytotoxicity of any DCM extract of the leaves of *A. pavarii* against various human cancer cell lines, as well as the bioassay-guided isolation of main compounds (**1** and **2**) from the bioactive fraction. While the distribution of arbutin (**1**) is quite widespread within the genus *Arbutus* (Elshibani et al., 2021), this is the first report on the isolation of triterpene acid ester from *A. pavarii*. However, related pentacyclic triterpenes were previously isolated from the fruits of another species of this genus, *A. unedo,* for example, α- and β-amyrin, betulinic acid, lupeol olean-12-en-3β,23-diol (Miguel et al., 2014). Similarly, the cytotoxic properties of the MeOH extract of the aerial parts of *A. pavarii* were previously demonstrated against both HepG2 hepatic carcinoma and T47D breast cancer cell lines, and the IC_{50} values were determined as 19.7 and 19.0 μg/mL, respectively (El Hawary et al., 2016). The cytotoxicity of the MeOH extract of the aerial parts of this plant was also shown against lung (A549) and breast (MCF7) cancer cell lines with IC_{50} values of below 30 μg/mL (Alsabri et al., 2013). Notably, this is the first report on the assessment of cytotoxicity of any DCM extract of *A. pavarii* against the bladder (EJ138) and prostate cancer (PC3) cell lines.

Arbutin (**1**) and its derivatives are known to possess cytotoxic as well as potential anticancer properties (Nahar et al., 2021). Several arbutin derivatives with an acylated glucosyl unit were isolated from the leaves of *Heliciopsis lobata* and shown to possess cytotoxic property against the gastric cancer MGC803 cells and to inhibit MGC803 cell invasion (Qi et al., 2016). In a recent study looking into the possible mechanism of action of arbutin (**1**), it was observed that this compound could display anticancer activity against rat C6 glioma cells by prompting apoptosis as well as by inhibiting inflammatory marker and phosphoinositide 3-kinase (PI3K)/mammalian target of rapamycin (mTOR) signaling molecules (Yang et al., 2021). Moreover, arbutin (**1**) could generate excessive reactive oxygen species and disrupt the mitochondrial membrane resulting in induction of apoptosis in cells. Arbutin (**1**) and a few other phenolic compounds were assessed for their cytotoxic property against two human breast cancer cell lines, adriamycin-resistant MCF-7/Adr and wild-type MCF-7/wt (Berdowska et al., 2013), and arbutin (**1**) was found active only against the MCF-7/Adr cell line with an IC_{50} value of 5.58 mM. Hydroquinone, the aglycone of arbutin (**1**), showed antiproliferative activity against C6 and HeLa (human cervix carcinoma) cells, while arbutin (**1**) did not show antiproliferative activity in all tested doses (Erenler et al., 2015). It can be noted here that C6 cells are spindle-like cells that can stimulate human glioblastoma when they are injected in the brain of neonatal rats, and this cell line is considered as the gold standard in glioma research.

Betulinic acid and its derivatives, e.g., betulinic acid methyl ester (**2**), are known to possess various bioactivities, including potential anticancer properties (Erenler et al., 2015). In a study conducted by Quang et al. (2018), betulinic acid methyl ester (**2**) as well as betulinic acid were tested for cytotoxicity against HeLa, HepG2, SK-LU-1 (human lung carcinoma), AGS (human stomach gastric adenocarcinoma) and SK-MEL-2 (human melanoma) cell lines, and it was found that both compounds could exert non-selective and a moderate level of cytotoxicity against all five cell lines. Betulinic acid methyl ester (**2**) was particularly active against the SK-LU-1 cell line with an IC_{50} value of 60.84 μg/mL, and the IC_{50} values against other cell lines were in between 66.17 and 80.17 μg/mL.

CONCLUSIONS

Bioassay-guided approach afforded isolation of arbutin (**1**) and betulinic acid methyl ester (**2**) as the main compounds present in the cytotoxic fraction of the DCM extract of the leaves of *A. pavarii*. The DCM extract showed considerable cytotoxicity against the prostate cancer cell line PC3, but much less toxicity against normal human prostate cell line PNT2, meaning cytotoxicity being more selective to cancer cells over normal cells. This is the first report on the isolation of betulinic acid methyl ester (**2**) from the leaves of *A. pavarii*. As both **1** and **2** were demonstrated previously to possess cytotoxic/antiproliferative properties against various human cell lines, and as they are present in the cytotoxic fraction of the DCM extract, it is reasonable to assume that the significant cytotoxicity of the DCM extract observed in the current study could be, at least partly, due to the presence of these two cytotoxic compounds. Further study involving these compounds and their structural analogues for their cytotoxic potential against human prostate cancer cell lines as well as mechanistic studies, e.g., apoptosis, necrosis and so on, could provide an insight into their structure-activity-relationships and possible mechanisms of action.

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Conflicts of interest

We declare no conflict of interest. The authors alone are responsible for the content and writing of the paper.

Authors' Contributions

AA carried out the laboratory work to generate data, supervised by ARE, LN, SDS and FMDI. SDS and LN wrote and edited the manuscript. All authors read and approved the manuscript.

Supplementary materials

Authors did not provide any Supplementary Materials.

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