Abstract
The synthesis of five novel methyl 10-undecenoate-based lipocunjugates of phenolic acids from undecenoic acid was carried out. Undecenoic acid was methylated to methyl 10-undecenoate which was subjected to a thiol–ene reaction with cysteamine hydrochloride. Further amidation of the amine was carried out with different phenolic acids such as caffeic, ferulic, sinapic, coumaric and cinnamic acid. All synthesized compounds were fully characterized and their structures were confirmed by spectral data. The anti-oxidant activity of the synthesized lipocunjugates of phenolic acids was studied by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay and also by the inhibition of linoleic acid oxidation in micellar medium by differential scanning calorimetry (DSC). The prepared compounds were also screened for their cytotoxic activity against five cell lines. It was observed that the lipocunjugates of caffeic acid, sinapic acid, ferulic acid, and coumaric acid displayed anticancer and anti-oxidant properties. The anticancer properties of these derivatives have been assessed by their IC$_{50}$ inhibitory values in the proliferation of MDA-MB231, SKOV3, MCF7, DU 145 and HepG2 cancer cell lines.

Introduction
Phenolic compounds are a class of natural compounds which are found ubiquitously in the plant kingdom. They are reported to possess a wide range of biological properties like anti-oxidant, antimicrobial, anti-inflammatory, anticarcinogenic and antiviral activities [1]. The phenolic acids are also reported to show in vitro anti-oxidant activity against many reactive oxygen
species and to protect neuronal cells against various types of oxidative damage [2,3]. To increase the effectiveness of phenolic compounds, their lipophilization has been the choice of derivatization as it provides beneficial effects of both the phenolics and the lipid involved in one chemical entity [4,5]. Lipids, especially fatty acids and their derivatives are known for their broad spectrum of activity which expands their application in developing new hybrid biomolecules which help in host defenses against potential pathogenic microbes. Research interest in producing new phenolipids has been increasing due to the potential applications of such products in biomedical fields. Earlier reports on the production of phenolipids were focused on the incorporation of phenolic compounds into triglycerides where a number of phenolic acids were transesterified with different oils or triglycerides [6]. Apart from these structured phenolipids, different fatty acids were esterified with phenolic compounds to produce novel esters which were evaluated for anti-oxidant and antimicrobial activities [7,8]. However, there are very few reports where the phenolic acids have been derivatized with other functionalities apart from esters. The reported compounds other than esters were amides where bioconjugates of fatty acids and amino acids were prepared and evaluated for their anti-oxidant activity by a DPPH radical assay [9]. In view of developing new conjugates of phenolic lipids, we have synthesized novel derivatives of phenolic lipids from undecenoic acid where the phenolic acids were linked to the olefinic group of undecenoic acid via a thioamide spacer. Among the various fatty acids reported, 10-undecenoic acid is unique due to its bifunctional nature with an odd-numbered carbon atom chain length derived from castor oil. There have been several reports on the synthesis and evaluation of undecenoic acid-based derivatives due to its wide applicability ranging from biological activity, natural products and polymer applications [10,11]. This type of compounds could be useful as potential novel lipid derivatives because of the presence of lipophilic chain and the phenolic amide conjugate.

Results and Discussion

Synthesis

10-Undecenoic acid was chosen as the lipid part as the derivatives of undecenoic acid have been reported to be potent bioactive compounds [12,13]. Additionally the terminal double bond of undecenoic acid provides a reactive group for further derivatization for producing potential functional derivatives. The synthetic route followed for the synthesis of the phenolipids is shown in Scheme 1. Initially, undecenoic acid was treated with sulfuric acid in methanol to obtain methyl undecenoate (1) in quantitative yield. Next, ester 1 was treated with 1,1′-azobis(cyclohexancarbonitrile) (ABCN) and 2-mercaptoethylamine hydrochloride in dioxane/ethanol 70:30 (v:v) to obtain

Scheme 1: Synthetic procedure for the preparation of 10-undecenoic acid methyl ester-based lipoconjugates of phenolic acids.
methyl 11-(2-aminoethylthio)undecanoate (2) in 89% yield. The structures of compounds 1 and 2 were in agreement with the reported literature data [14,15].

Finally, amine 2 was reacted with different phenolic acids in the presence of EDC·HCl and HOBt to give amides 3a–3e with reproducible yields in the range of 84–86%.

**Anti-oxidant activity**

The anti-oxidant activities of the prepared derivatives were studied by the well-established DPPH radical scavenging assay and also by studying the oxidation of linoleic acid using DSC. The DPPH radical is a commercially available stable free radical which is widely used to preliminarily determine the radical scavenging potential of compounds. The results for the ability of the prepared compounds to scavenge the DPPH radical are shown in Table 1 along with reference anti-oxidants α-tocopherol (α-TP) and tert-butylhydroquinone (TBHQ). As can be seen, all synthesized derivatives exhibit radical scavenging ability except the cinnamic acid derivative 3a. This could be due to the absence of a phenolic hydroxy group which is responsible for the anti-oxidant activity of most of the natural phytochemicals. Among all compounds, 3c was found to be the most efficient free radical scavenger which showed a value closest to the standard anti-oxidant, α-TP. Compounds 3d and 3e also showed free radical scavenging activity (FRSA) of 68% and 67%, respectively, whereas compound 3b showed only moderate activity with 30% FRSA.

| Compound | FRSA (%) at 1.0 mM concentration |
|----------|----------------------------------|
| 3a       | 30.23                            |
| 3b       | 87.05                            |
| 3c       | 67.68                            |
| 3d       | 66.57                            |
| 3e       | 90.23                            |
| α-TP     | 92.34                            |
| TBHQ     |                                   |

In another study, the ability of the prepared derivatives in inhibiting the oxidation of linoleic acid was studied by differential scanning calorimetry (DSC). DSC is a sensitive technique and has been used for investigating the thermotropic properties of several compounds including biological macromolecules, drugs and lipid-based materials for their stability and other characteristics [16]. In the present study, pure linoleic acid and linoleic acid containing the synthesized compounds were subjected to DSC analysis. The results of the assay are shown in Table 2 and α-TP and TBHQ were included as standard anti-oxidants.

**Table 2: DSC study of the synthesized 10-undecenoic acid methyl ester-based lipoconjugates 3a–e.**

| Compound  | OIT⁰ (°C) |
|-----------|-----------|
| LA + 3a   | 116       |
| LA + 3b   | 130       |
| LA + 3c   | 136       |
| LA + 3d   | 141       |
| LA + 3e   | 142       |
| LA + α-TP | 130       |
| LA + TBHQ | 126       |
| LA        | 116       |

⁰LA: linoleic acid, OIT: oxidative induction temperature.

Pure linoleic acid showed an oxidative induction temperature (OIT) of 116 °C which was found to increase when anti-oxidants were added. It can be observed that the prepared derivatives had a positive influence on the oxidation of linoleic acid except for derivative 3a which did not show any anti-oxidant activity (see Supporting Information File 1, Figure S20 for DSC curves). All other derivatives were found to exhibit very good protective activity against oxidation of linoleic acid and the OITs were found to be similar or in case of compounds 3c, 3d and 3e even higher compared to the reference anti-oxidants TBHQ and α-TP. The OIT for TBHQ and α-TP were observed to be 126 and 130 °C, respectively, whereas compound 3b showed an OIT of 130 °C. As the anti-oxidant activity has been reported [17] to depend on several factors such as the medium of an assay, number and position of phenolic hydroxy groups, etc. the differences in the anti-oxidant potentials of the prepared phenolipids could be due to different media used for the assays; the DPPH assay is conducted in a polar medium but the linoleic acid oxidation study is conducted in a non-polar environment.

**Cytotoxic activity**

As there were studies reported on the cytotoxicity of phenolic lipids, we have further screened the prepared compounds for their anticancer activity [18]. The anticancer activity of compounds 3a–e was tested against five cell lines along with doxorubicin as positive control and all of them showed moderate to good anticancer effects. The results are collected in Table 3. The compounds whose IC₅₀ values are observed to be lower and closer to the reference drug are considered as having good anticancer potential.
Specifically compounds 3c, 3b and 3e were found to show promising anticancer activity according to their IC\textsubscript{50} values, whereas 3d and 3a exhibited only moderate activity. Among all tested derivatives, compound 3e was found to exhibit best anticancer activity against MCF7, DU145 and MDA-MB-231 cell lines with IC\textsubscript{50} values of 10.55, 13.0 and 12.0 \textmu M, respectively. It was found that the anticancer activity against some cell lines was much better compared to our previous reports on phenolic lipids [19]. However, all prepared derivatives were observed to exhibit lower anticancer activity when compared to the reference drug doxorubicin which showed excellent anti-oxidant activity. Finally the novel phenolic lipids as anti-oxidants was studied using the dpph radical scavenging assay and dsc studies where some compounds showed excellent anti-oxidant activity. Finally the compounds were further screened for anticancer activity where a few derivatives showed interesting activity.

**Instruments**

\textsuperscript{1}H and \textsuperscript{13}C NMR spectra were recorded on a Bruker Avance operating at 700/500 MHz and 175/125 MHz. The NMR spectra were referenced to \textdelta 7.26 ppm and \textdelta 77.0 ppm in CDCl\textsubscript{3} solvent for \textsuperscript{1}H and \textsuperscript{13}C, respectively. Coupling constants (J) patterns in the \textsuperscript{1}H NMR spectra are given as follows: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet protons. Mass spectra were recorded using electron spray ionization (ESI) on a Waters e2695 Separators module (Waters, Milford, MA, USA) mass spectrometer. FTIR spectra were recorded in chloroform on a Perkin–Elmer Fourier Transform (FTIR) spectrum BX instrument (Model: Spectrum BX; Connecticut, USA). HRMS spectra were obtained from an Exactive Orbitrap mass spectrometer (Thermo Scientific, Waltham, MA, USA). Melting points of lipoconjugates of phenolic molecules were determined with a capillary tube melting point apparatus. Gas chromatography (GC) was performed on an Agilent 6890N gas chromatograph (Delaware, USA) equipped with a flame ionization detector using a HP-1 capillary column (30 m \times 0.25 mm \times 0.25 \textmu m). The injector and detector temperatures were set at 280 and 300 °C, respectively. The oven temperature was programmed at 150 °C for 2 min and then increased to 300 °C at 10 °C/min and final temperature hold for 20 min. The carrier gas used was nitrogen at a flow rate of 1.0 mL/min.

**Methods**

**Synthesis of methyl undec-10-enoate (1):** 10-Undecenoic acid (10 g, 54.34 mmol), was added to methanol (17.6 mL) and sulfuric acid (0.1 mL, 2 wt % 10-undecenoic acid) and stirred at

### Table 3: Anticancer activity of 10-undecenoic acid methyl ester–based lipoconjugates.\textsuperscript{a}

| Entry | Compound | MDA-MB-231 | SKOV3 | MCF7 | DU145 | HepG2 |
|-------|----------|------------|-------|------|-------|-------|
| 1     | 3a       | 21.2 ± 0.31| 99.2 ± 0.79| 17.2 ± 0.23| 25.4 ± 0.31| 38.2 ± 0.42 |
| 2     | 3b       | 14.5 ± 0.26| 31.5 ± 0.41| 39.2 ± 0.45| 81.6 ± 0.77| 58.3 ± 0.61 |
| 3     | 3c       | 12.0 ± 0.28| 38.9 ± 0.37| 10.55 ± 0.27| 13.0 ± 0.26| 67.4 ± 0.59 |
| 4     | 3d       | 29.0 ± 0.36| 32.2 ± 0.32| 28.8 ± 0.36| 56.7 ± 0.62| 93.9 ± 0.85 |
| 5     | 3e       | 12.5 ± 0.25| 38.3 ± 0.40| 13.9 ± 0.22| 28.8 ± 0.39| 141.4 ± 0.98|
|       | doxorubicin| 0.8 ± 0.14| 0.7 ± 0.16| 0.8 ± 0.12| 0.8 ± 0.15| 0.7 ± 0.14 |

\textsuperscript{a}Cell lines: MDA-MB-231, breast cancer (ATCC® HTB-26™); SKOV3, ovarian cancer (ATCC® HTB-77™); MCF7, breast cancer (ATCC® HTB-22™); DU 145, prostate cancer (ATCC® HTB-81™); HepG2, liver hepatocellular carcinoma (ATCC® HB-8066™).
refluxing temperature of methanol for 6 h. After completion of the reaction as shown by TLC (hexane/ethyl acetate 80:20, v/v), excess methanol was removed under reduced pressure and the product was diluted with ethyl acetate (30 mL), washed with 5% aqueous NaHCO₃ solution (3 × 30 mL), and dried over anhydrous Na₂SO₄. The organic solvent was removed under reduced pressure to afford crude methyl ester of 10-undecenoic acid. The product was purified by column chromatography with basic alumina and hexane as the eluent to get 99% pure methyl undec-10-enoate (1) as indicated by GC. The product was analyzed by ¹H NMR, ¹³C NMR, ESIMS, and FTIR and the structure was confirmed by comparing the data with those reported in the literature [14].

Synthesis of methyl 11-((2-aminoethylthio)undecanoate (2): For the synthesis of compound 2, a reported protocol was followed with slight modifications [20]. Briefly, methyl undecenoate (1, 6 g, 30.3 mmol) and ABCN (0.18 g, 3 wt % of 1) were dissolved in 40 mL chloroform. Then, 2-mercaptoethylamine hydrochloride (0.4 g, 2.52 mmol) and HOBt (0.3 g, 2.11 mmol) and cinnamic acid (0.6 g, 2.1 mmol) were added. The mixture was stirred at 0–5 °C under a nitrogen atmosphere and the progress of reaction was monitored by TLC (hexane/ethyl acetate 80:20, v/v) for 10 min. After the addition, the mixture was stirred for 12 h at rt under a nitrogen atmosphere and the progress of reaction was monitored by TLC using the solvent system chloroform/methanol (80:20, v/v). After maximum conversion, the reaction mixture was extracted with dichloromethane, washed with water and dried over anhydrous Na₂SO₄ and concentrated to obtain the crude product. The crude product was purified by column chromatography (chloroform/methanol 90:10, v/v) to obtain the thioamide of cinnamic acid in 86% yield (0.73 g).

The product was characterized by ¹H and ¹³C NMR, IR, ESIMS and HRMS spectral studies. Mp 55–56 °C; ¹H NMR (500 MHz, CDCl₃) δ 7.64 (d, J = 15.6 Hz, 1H), 7.54–7.46 (m, 5H), 6.24 (d, J = 15.6 Hz, 1H), 3.66 (s, 3H), 3.56 (q, 2H), 2.73 (t, 2H), 2.58 (t, 2H), 2.30 (t, 2H), 1.24–1.62 (m, 12H, CH₂). ¹³C NMR (75 MHz, CDCl₃) δ 174.37 (−C(O)-OCH₃), 166.84 (−NH-), 151.41 (−NH-C(CH₃)), 115.98, 51.58 (−C(O)-OCH₃), 38.63 (−CH₂-NH), 34.16 (−S-CH₂), 31.89 (−CH₂-S), 31.84 (−CH₂-CH₂-S), 29.69–24.96 (−CH₂-CH₂-); IR (cm⁻¹, KBr): 3359, 2953, 2854, 1721, 1654, 1599, 1519, 1452, 1373; ESIMS (m/z): 422 [M + H]⁺, 444 [M + Na]⁺; HRMS (m/z): [M + H]⁺ calecd for C₂₃H₂₆O₂NS, 422.2356; found, 422.2349.

Synthesis of methyl 11-((2-(2-(4-hydroxyphenyl)acrylamido)ethyl)sulfanyl)undecanoate (3b): Similarly, methyl 11-((2-(4-hydroxyphenyl)acrylamido)ethyl)sulfanyl)undecanoate (3b) was prepared from 2 (0.6 g, 2.1 mmol) and caffeic acid (0.5 g, 3.2 mmol) in 85% yield (0.78 g) and the product was characterized by ¹H and ¹³C NMR, IR, ESIMS and HRMS spectral studies. Mp 64–65 °C; ¹H NMR (500 MHz, CDCl₃) δ 7.57 (d, J = 15.6 Hz, 1H), 7.39 (d, J = 8.6 Hz, 1H), 6.85 (d, J = 8.6 Hz, 1H), 6.26 (d, J = 15.6 Hz, 1H), 3.67 (s, 3H), 3.58 (q, 2H), 2.73 (t, 2H), 2.58 (t, 2H), 2.30 (t, 2H), 1.24–1.62 (m, 12H, CH₂); ¹³C NMR (75 MHz, CDCl₃) δ 174.71 (−C(O)-OCH₃), 166.84 (−NH-), 141.51 (−NH-C(CH₃)), 129.64, 128.99, 117.32 (−NH-C(CH₃)), 115.98, 51.58 (−C(O)-OCH₃), 38.63 (−CH₂-NH), 34.16 (−S-CH₂), 31.89 (−CH₂-S), 31.84 (−CH₂-CH₂-S), 29.69–24.96 (−CH₂-CH₂-); IR (cm⁻¹, KBr): 3409, 2923, 2853, 1729, 1652, 1595, 1519, 1452, 1373; ESIMS (m/z): 422 [M + H]⁺, 444 [M + Na]⁺; HRMS (m/z): [M + H]⁺ calecd for C₂₃H₂₆O₂NS, 422.2356; found, 422.2349.
Synthesis of methyl 11-((2-((E)-3-(4-hydroxy-3-methoxy-phenyl)acrylamido)ethyl)sulfanyl)undecanoate (3d): Similarly, methyl 11-((2-(E)-3-(4-hydroxy-3-methoxyphenyl)acrylamido)ethyl)sulfanyl)undecanoate was prepared from 2 (0.6 g, 2.1 mmol) and ferulic acid (0.6 g, 3.2 mmol) in 84% yield (0.82 g) and the product was characterized by \(^1\)H and \(^13\)C NMR, IR, ESIIMS and HRMS spectral studies. \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 7.55\) (d, \(J = 15.5\) Hz, 1H), 7.06 (dd, \(J = 8.2, 1.5\) Hz, 1H), 7.00 (d, \(J = 1.6\) Hz, 1H), 6.91 (d, \(J = 8.2\) Hz, 1H), 6.27 (d, \(J = 15.5\) Hz, 1H), 3.92 (s, 3H), 3.67 (s, 3H), 3.58 (q, 2H), 2.73 (t, 2H), 2.58 (t, 2H), 2.30 (t, 2H), 1.24–1.62 (m, 12H, CH\(_2\)); \(^13\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 174.36\) (C=O), 138.82 (CH=CH), 132.67 (CH=C), 127.33, 122.22, 118.06 (CH=C), 114.76, 109.64, 55.95 (CH\(_2\)), 51.45 (CH=CH), 38.42 (CH\(_2\)), 34.11 (CH\(_2\)), 35.04 (CH\(_2\)), 29.47–24.95 (CH\(_2\)), IR (cm\(^{-1}\), KBr): 3375, 2926, 2853, 1730, 1656, 1596, 1516, 1433, 1273; ESIIMS (m/z): 452 [M + H]\(^+\), 474 [M + Na]\(^+\); HRMS (m/z): [M + H]\(^+\) calcd for C\(_{24}\)H\(_{38}\)O\(_5\)NS, 452.24652; found, 452.24475.

Synthesis of methyl 11-((2-((E)-3-(4-hydroxy-3,5-dimethoxy-phenyl)acrylamido)ethyl)sulfanyl)undecanoate (3e): Similarly, methyl 11-((2-(E)-3-(4-hydroxy-3,5-dimethoxyphenyl)acrylamido)ethyl)sulfanyl)undecanoate was prepared from 2 (0.6 g, 2.1 mmol) and sinapic acid (0.7 g, 3.2 mmol) in 84% yield (0.89 g) and the product was characterized by \(^1\)H and \(^13\)C NMR, IR, ESIIMS and HRMS spectral studies. Mp 69–70 °C; \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 7.53\) (d, \(J = 15.5\) Hz, 1H), 6.76 (s, \(J = 8.2, 1.5\) Hz, 2H), 6.28 (d, \(J = 15.5\) Hz, 1H), 3.93 (s, 6H), 3.67 (s, 3H), 3.58 (q, 2H), 2.73 (t, 2H), 2.58 (t, 2H), 2.30 (t, 2H), 1.24–1.62 (m, 12H, CH\(_2\)); \(^13\)C NMR (75 MHz, CDCl\(_3\)) \(\delta 177.89\) (C=O), 136.07 (CH=CH), 132.67 (CH=C), 127.33, 122.22, 118.06 (CH=C), 114.76, 109.64, 55.95 (CH\(_2\)), 51.45 (CH=CH), 38.42 (CH\(_2\)), 34.11 (CH\(_2\)), 35.04 (CH\(_2\)), 29.47–24.95 (CH\(_2\)), IR (cm\(^{-1}\), KBr): 3375, 2926, 2853, 1730, 1656, 1596, 1516, 1433, 1273; ESIIMS (m/z): 452 [M + H]\(^+\), 474 [M + Na]\(^+\); HRMS (m/z): [M + H]\(^+\) calcd for C\(_{24}\)H\(_{38}\)O\(_5\)NS, 452.24652; found, 452.24475.
Supporting Information

Supporting Information File 1
Copies of $^1$H NMR, $^{13}$C NMR, HRMS and DSC spectra.
[http://www.beilstein-journals.org/bjoc/content/supplementary/1860-5397-13-4-S1.pdf]

Acknowledgements
Naganna Narra thanks the University Grants Commission (UGC), New Delhi, India, for financial support through a Senior Research Fellowship (UGC-SRF).

References
1. Figueroa-Espinoza, M.-C.; Villeneuve, P. J. Agric. Food Chem. 2005, 53, 2779. doi:10.1021/jf0484273
2. Shahidi, F.; Chandrasekara, A. Phytochem. Rev. 2010, 9, 147. doi:10.1007/s11101-009-9142-8
3. Garrido, J.; Gaspar, A.; Garrido, E. M.; Miri, R.; Tavakkoli, M.; Pourali, S.; Saso, L.; Borges, F.; Finuži, O. Biochimie 2012, 94, 961. doi:10.1016/j.biochi.2011.12.015
4. Crauste, C.; Rosell, M.; Durand, T.; Vercauteren, J. Biochimie 2016, 120, 62. doi:10.1016/j.biochi.2015.07.018
5. Mbatia, B.; Kaki, S. S.; Mattiasson, B.; Mulaa, F.; Adlercreutz, P. J. Agric. Food Chem. 2011, 59, 7021. doi:10.1021/jf200867r
6. Sun, S.; Zhu, S.; Bi, Y. Food Chem. 2014, 158, 292. doi:10.1016/j.foodchem.2014.02.146
7. Yasa, S. R.; Kaki, S. S.; Bhaskara Rao, B.; Jain, N.; Penumarthy, V. Med. Chem. Res. 2016, 25, 1299. doi:10.1007/s00044-016-1564-4
8. Kaki, S. S.; Kunduru, K. R.; Kanjilal, S.; Prasad, R. B. N. J. Oleo Sci. 2015, 64, 845. doi:10.5650/jos.ess15033
9. Hunneche, C. S.; Lund, M. N.; Skibssted, L. H.; Nielsen, J. J. Agric. Food Chem. 2008, 56, 9288. doi:10.1021/jf8024826
10. Van der Steen, M.; Stevens, C. V. ChemSusChem 2009, 2, 692. doi:10.1002/cssc.200900075
11. Sammaiah, A.; Kaki, S. S.; Sai Manoj, G. N. V. T.; Poomachandra, Y.; Kumar, C. G.; Prasad, R. B. N. Eur. J. Lipid Sci. Technol. 2015, 117, 692. doi:10.1002-ejlt.201400471
12. Doležalová, M.; Janiš, R.; Svobodová, H.; Kašpárková, V.; Humpolíček, P.; Krejčí, J. Eur. J. Lipid Sci. Technol. 2010, 112, 1106. doi:10.1002/ejlt.200900295
13. Tokiya, Y.; Kitagawa, M.; Raku, T.; Yanagitani, S.; Yoshino, K. Bioorg. Med. Chem. Lett. 2007, 17, 3105. doi:10.1016/j.bmcl.2007.03.039
14. Jacobson, C. E.; Martínez-Muñoz, N.; Gorin, D. J. J. Org. Chem. 2015, 80, 7305. doi:10.1021/ac5010777
15. Türüń, O.; Firdaus, M.; Klein, G.; Meier, M. A. R. Green Chem. 2012, 14, 2577. doi:10.1039/C2GC35982K
16. Chiu, M. H.; Prendergast, E. J. J. Pharm. BioAllied Sci. 2011, 3, 39. doi:10.4103/0975-7406.74663
17. Silva, F. A. M.; Borges, F.; Guimarães, C.; Lima, J. L. F. C.; Matos, C.; Reis, S. J. Agric. Food Chem. 2000, 48, 2122. doi:10.1021/jf9913110
18. Stasiuk, M.; Kozubek, A. Cell. Mol. Life Sci. 2010, 67, 841. doi:10.1007/s00018-009-0193-1
19. Kaki, S. S.; Gopai, S. C.; Rao, B. V. S. K.; Poomachandra, Y.; Kumar, C. G.; Prasad, R. B. N. Eur. J. Lipid Sci. Technol. 2013, 115, 1123. doi:10.1002-ejlt.201300179
20. Sammaiah, A.; Padmaja, K. V.; Prasad, R. B. N. Eur. J. Lipid Sci. Technol. 2016, 116, 495. doi:10.1002/elixt.201500119
21. Kaki, S. S.; Arukali, S.; Padmaja, K. V.; Prasad, R. B. N.; Yedla, P.; Kumar, C. G. Bioorg. Med. Chem. Lett. 2016, 26, 209. doi:10.1016/j.bmcl.2015.10.086
22. Akowuah, G. A.; Zhari, I.; Norhayati, I.; Mariam, A. J. Food Compos. Anal. 2006, 19, 118. doi:10.1016/j.jfca.2005.04.007
23. Gaspar, A.; Martins, M.; Silva, P.; Garrido, E. M.; Garrido, J.; Finuži, O.; Miri, R.; Saso, L.; Borges, F. J. Agric. Food Chem. 2010, 58, 11273. doi:10.1021/jf103075r
24. Reis, B.; Martins, M.; Barreto, B.; Milhazes, N.; Garrido, E. M.; Silva, P.; Garrido, J.; Borges, F. J. Agric. Food Chem. 2010, 58, 6986. doi:10.1021/jf100569j
25. Bolu, V. S.; Nethi, S. K.; Dasari, R. K.; Shiva Nageshwar Rao, S.; Misra, S.; Patra, C. R. Nanotoxicology 2015, 10, 413. doi:10.3109/17435390.2015.1073398

License and Terms
This is an Open Access article under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

The license is subject to the Beilstein Journal of Organic Chemistry terms and conditions: (http://www.beilstein-journals.org/bjoc)

The definitive version of this article is the electronic one which can be found at: doi:10.3762/bjoc.13.4