

Miconidin Acetate and Primin as Potent 5-Lipoxygenase Inhibitors from Brazilian Eugenia hiemalis (Myrtaceae)

Gabrielle Andressa Zatelli1, Veronika Temml2, Zsofia Kutil3, Premysl Landa3, Tomas Vanek3, Daniela Schuster4, Miriam Falkenberg1

1 Laboratory of Natural Products, Department of Pharmaceutical Sciences, Federal University of Santa Catarina, Florianopolis, Brazil
2 Institute of Pharmacy/Pharmacognosy, Institute of Pharmacy and Center for Molecular Biosciences Innsbruck (CMBI), Innsbruck, Austria
3 Laboratory of Plant Biotechnologies, Institute of Experimental Botany AS CR, v. v. i., Prague, Czech Republic
4 Computer-Aided Molecular Design Group, Institute of Pharmaceutical Chemistry, and Center for Molecular Biosciences Innsbruck (CMBI), Innsbruck, Austria

Abstract

This paper describes the isolation and identification of primin and miconidin acetate as metabolites from the flower bud extract of Eugenia hiemalis as well as the anti-inflammatory activity of miconidin acetate by inhibition of 5-lipoxygenase. Miconidin acetate inhibited leukotriene B4 formation catalyzed by the human recombinant enzyme (IC50 = 0.3 ± 0.17 µM) more than primin (IC50 = 1.4 ± 0.6 µM) and zileuton (IC50 = 1.1 ± 0.7 µM). Miconidin acetate (20 µM) inhibited LTB4 formation to an extent of 59 ± 12% in vitro using a cell-based assay, comparable to the positive control zileuton (69 ± 12% inhibition at a concentration of 10 µM). The binding modes of miconidin acetate were further evaluated in silico by molecular docking to the human 5-lipoxygenase crystal structure. The hydroxyl group was predicted to form a hydrogen bond with the terminal Ile676, while the pentyl moiety occupied the hydrophobic substrate channel. The obtained results show that flower buds of E. hiemalis are an interesting source of anti-inflammatory compounds, mainly of miconidin acetate.

Key words

Eugenia hiemalis · Myrtaceae · miconidin acetate · primin · anti-inflammatory · 5-lipoxygenase

Supporting information available online at http://www.thieme-connect.de/products

Eugenia is the largest genus in the Myrtaceae family from tropical America [1], growing from Mexico and the Caribbean to Argentina [2]. The plants of this genus are evergreen trees or shrubs with usually edible fruits and are known to be rich in volatile oils [3,4]. Several species are used in folk medicine as anti-inflammatory [5], diuretic, digestive [6], and antimicrobial remedies [7]. Eugenia hiemalis Cambess., commonly known as “guamirim”, is a tree that grows in Brazil, Argentina, Uruguay, and Paraguay [8]. There are a few reports on its chemical composition and biological activity. Nevertheless, no report of its traditional use was found for this species. A benzoquinone (primin) and a monoacetyl derivative of the correspondent hydroquinone were isolated from the extract of leaves collected in Southern Brazil [9]. Both compounds showed antipapoptotic activity towards KG1a cells [10]. Moreover, three galloyl arbutins (hyemalosides A–C) along with nine phenolic compounds were isolated from the leaves’ extract from plants growing in Paraguay. Some of these compounds inhibited HIV–1 RNase H in vitro [11]. The essential oil from the leaves contained sesquiterpene hydrocarbons as the major components [12, 13].

Natural products have long been used in folk medicine for the treatment of inflammatory conditions such as fevers, pain, and arthritis. These bioactive plant-derived substances represent a wide structural diversity. Some examples include curcumin, resveratrol, baicalin, boswellic acid, betulinic acid, ursoic acid, and oleanolic acid, which act on several inflammatory targets like cyclooxygenases (COX-1 and COX-2), 5-lipoxygenase (5-LOX), cytokines, chemokines, or interleukins [14].

Previous work evaluating primin detected a strong selective inhibition of COX-2 over COX-1 [15]. Furthermore, primin was similarly as potent as the 5-LOX inhibitor and reference compound zileuton, which is clinically used for asthma treatment. Docking analysis showed that the benzoquinone structure was essential for this activity [16]. This paper describes the isolation of miconidin acetate (MA) (1) and primin (2) (Fig. 1) by chromatographic isolation of the flower bud extract from E. hiemalis, their anti-inflammatory activities via 5-LOX inhibition, and a docking analysis of MA binding to the target. Both compounds were identified and confirmed by spectral data and comparison to the literature. MA was the major metabolite and constitutes a hydroquinone derivative related to primin.

In the search for protein targets mediating a possible anti-inflammatory effect of MA, a similarity ensemble approach (SEA) was pursued using the publicly available SEA search tool [17, 18]. The structure of MA was uploaded as smiles code. MA was then compared to structurally similar molecule ensembles from the ChEMBL binding database. If the similarity was high, MA was predicted to act on the same biological targets at the same concentration as the respective molecules from the ChEMBL. We considered all predictions with E-values ≤−4, as suggested by Loukine et al. [19]. Among the 54 predicted targets for MA, the 8th-ranked target, rat 5-lipoxygenase (5-LOX), was linked to inflammation. Overall, 5-LOX from different species was proposed five times as a target by the SEA tool.

MA inhibited leukotriene B4 (LTB4) formation in the human recombinant enzyme (IC50 = 0.3 ± 0.17 µM) more potently than primin (IC50 = 1.4 ± 0.6 µM) and zileuton (IC50 = 1.1 ± 0.7 µM). Primin previously inhibited LTB4 biosynthesis in a cell-based assay with an IC50 of 4.1 µM [16]. Therefore, MA was also evaluated for 5-LOX inhibition in vitro using a cell-based

Fig. 1 Chemical structures of MA (1) and primin (2).
assay and detecting LTB₄ with an ELISA kit [20]. MA (20 µM) inhibited LTB₄ formation to an extent of 59±12 %, while the positive control zileuton (10 µM) inhibited 5-LOX by 69±12 %. The inhibitory activity in the cell-free assay demonstrated direct interferences of MA and primin with 5-LOX’s catalytic activity. In the case of cell-based assays, tested compounds can actually interact with several targets within the 5-LOX activation and reaction cascade [21]. In our case, the activity of MA in the cell-based assay demonstrated mainly its ability to enter the cells.

To further elucidate the mode of inhibition, MA was docked into an X-ray crystal structure of human 5-LOX (PDB entry 3o8 y) [22] using GOLD 5.2 (CCDC, GB). As shown in FIG. 2, MA was predicted to occupy part of the active site going by the iron ion. It formed a hydrogen bond with the iron-coordinating residue Ile676 and hydrophobic contacts in the tunnel leading to the catalytic center.

Miconidin has been considered the biosynthetic precursor of primin [23, 24], and the isolation of MA as a major compound in the floral buds suggests that this metabolite is a storage form for primin [23, 24], and the isolation of MA as a major compound in Miconidin has been considered the biosynthetical precursor of alytic center.

Ile676 and hydrophobic contacts in the tunnel leading to the catalytic center.

Material and Methods

General experimental procedures: NMR spectra were obtained by Bruker DRX 400, Bruker AMX 500, and Varian XL 300 spectrometers for the 1H NMR, 13C NMR, correlation spectroscopy (COSY), heteronuclear multiple-quantum correlation (HMQC), and heteronuclear multiple-bond correlation (HMBC). The mass spectrum was recorded by a spectrometer MS 50 (Kratos). IR spectra were obtained by a Prestige-21 Shimadzu, and UV–Vis spectra by Perkin Elmer Lambda 10.

Plant material: The aerial parts of E. hiemalis were collected and identified in April 2014 in Porto Alegre (Rio Grande do Sul, Brazil). A voucher specimen (ICN 127910) was deposited in the herbarium of the Instituto de Ciências Naturais (Federal University of Rio Grande do Sul).

Extraction and isolation: The flower buds (27 g) were extracted with dichloromethane (0.25 L) by maceration for 7 days. The extract was concentrated under reduced pressure affording 0.5 g of CH₂Cl₂ extract that was fractionated in a gravity chromatography column on silica gel (40–63 µm, Sigma-Aldrich; 2.5 × 40 cm) with hexane-ethyl acetate (100/0 to 0/100, flow rate 1 mL/min) to give 1 (138.2 mg) and 2 (43.6 mg).

In vitro 5-lipoxygenase assay: Inhibition of 5-LOX was determined in two assays: a cell-based assay [20] and a cell-free assay using human recombinant enzyme (modified method of Albert et al.) [26]. Human neutrophil granulocytes for the cell-based assay were isolated from buffy coat (50 mL) obtained from healthy donors. Dextran solution was used for sedimentation, and subsequent lysis and washing were performed. Isolated cells were diluted to a final concentration of 4500 cells/µL. The incubation mixture consisted of 225 µL of cell suspension, 10 µL of 2 mM CaCl₂, 10 µL of 10 µM eicosatetraenoic acid, 5 µL of tested substances dissolved in DMSO, 10 µL of 21 µM calcium ionophor A23187, and 5 µL of 120 µM arachidonic acid. The reaction was stopped after 10 min incubation at 37 °C and the concentration of LTB₄ was measured using a commercial LTB₄ ELISA kit (Enzo Life Sciences) according to the manufacturer’s instructions. Absorbance relative to the LTB₄ concentration was measured at 405 nm using a Tecan Infinite M200 (Tecan Group). The results are expressed as percentage of inhibition of LTB₄ formation against untreated samples (blanks).

Human recombinant 5-LOX (Cayman Chemical) was used for the cell-free assay. 5-LOX (1 unit/reaction) was added to 180 µL of incubation mixture consisting of phosphate buffer saline (pH 7.4), 1 mM of Na₂EDTA, and 200 of µM ATP. After the addition of the test substances (10 µL) dissolved in DMSO (or pure DMSO in case of blank), the mixture was incubated for 10 min at 4°C. Then 5 µL of 80 mM CaCl₂ and 5 µL of 800 µM arachidonic acid were added and the mixture was incubated for 10 min at 37 °C. The reaction was terminated by the addition of 10 µL of 10% formic acid. All samples were diluted 1:15 in assay buffer and the main product of reaction, LTB₄, was quantified using an LTB₄ ELISA kit (Enzo Life Sciences) according to the manufacturer’s instructions. At least four concentrations were used for the calculations of the IC₅₀ values. Three independent experiments with at least two replicates were used for the calculations of the inhibition curves. IC₅₀ values were determined by regression analyses using Microsoft Excel.

Docking analysis: A putative binding mode for MA was calculated employing molecular docking using GOLD 5.2 software (www.ccdc.cam.ac.uk). Before docking, MA was geometrically opti-
mized using Biovia DiscoveryStudio (www.biovia.com). The binding site was defined in a 10-Å radius around the iron ion in the catalytically active center. For all other options, default settings were used.

Supporting information
Spectral and physicochemical data of MA (1) and primin (2), and also a graphic of the inhibition of LTB4 formation in the human recombinant enzyme by these compounds, are available as Supporting Information.

Acknowledgements
G.A.Z. is thankful to CAPES for the MSc. fellowship. The authors thank Prof. Vassilios Roussis (University of Athens) for the NMR spectra of MA.

Conflict of Interest
The authors declare no conflict of interest.

References
20 Adams M, Kunert O, Haslinger E, Bauer R. Inhibition of leukotriene biosynthesis by quinolone alkaloids from the fruits of Evodia rutaecarpa. Planta Med 2004; 70: 904–908
23 Connolly M, Cune JM, Dauncey E, Lovell CR, Primula obconica – is contact allergy on the decline? Contact Dermatitis 2004; 51: 167–171
24 Krebs M, Christensen LP. 2-methoxy-6-pentyl-1,4-dihydroxybenzene (miconidin) from Primula obconica: a possible allergen? Contact Dermatitis 1995; 33: 90–93

License terms

Letter e19

Zatelli GA et al. Miconidin Acetate and... Planta Med Lett 2016; 3: e17–e19