EDITOR-IN-CHIEF
DR. Pawan K Agrawal
Natural Product Inc.
7963, Anderson Park Lane,
Westerville, Ohio 43081, USA
agrawal@naturalproduct.us

EDITORS
PROFESSOR ALESSANDRA BRACA
Dipartimento di Chimica Bioorganicae Biofarmacia,
Università di Pisa,
via Bonanno 33, 56126 Pisa, Italy
braca@farm.unipi.it

PROFESSOR DEAN GUO
State Key Laboratory of Natural and Biomimetic Drugs,
School of Pharmaceutical Sciences,
Peking University,
Beijing 100871, China
guod@pharmacy.ac.uk

PROFESSOR J. ALBERTO MARCO
Departamento de Quimica Organica,
Universidad de Valencia,
E-46100 Burjassot, Valencia, Spain
jalmarco@uv.es

PROFESSOR YASUHIRO MIMAKI
School of Pharmacy,
Tokyo University of Pharmacy and Life Sciences,
Horinouchi 1432-1, Hachioji, Tokyo 192-0392, Japan
mimakiy@ps.toyaku.ac.jp

PROFESSOR STEPHEN G. PYNE
Department of Chemistry,
University of New South Wales,
Sydney, New South Wales, 2522, Australia
spyne@unsw.edu.au

PROFESSOR MANFRED G. REINECKE
Department of Chemistry,
Texas Christian University,
Fort Worth, TX 76129, USA
m.reinecke@tcu.edu

PROFESSOR WILLIAM N. SETZER
Department of Chemistry
The University of Alabama in Huntsville
Huntsville, AL 35809, USA
wsetzer@chemistry.uah.edu

PROFESSOR YASUHIRO TEZUKA
Institute of Natural Medicine
Institute of Natural Medicine, University of Toyama,
2830-Sugitani, Toyama 930-0194, Japan
tezuka@inn.u-toyama.ac.jp

PROFESSOR DAVID E. THURSTON
Department of Pharmaceutical and Biological Chemistry,
The School of Pharmacy,
University of London, 29-39 Brunswick Square,
London WC1N 1AX, UK
david.thurston@pharmacy.ac.uk

ADVISORY BOARD
Prof. Berhanu M. Abebe
Gaborone, Botswana
Prof. Václav Uddin Ahmad
Karachi, Pakistan
Prof. Øyvind M. Andersen
Bergen, Norway
Prof. Giovanni Appendino
Novara, Italy
Prof. Yoshinori Asakawa
Tokushima, Japan
Prof. Lee Banting
Portsmouth, U.K.
Prof. Julie Banerji
Kolkata, India
Prof. Anna R. Blia
Florence, Italy
Prof. Maurizio Bruno
Palermo, Italy
Prof. Josep Coll
Barcelona, Spain
Prof. Geoffrey Cordell
Chicago, IL, USA
Prof. Cristina Gracia-Viguera
Murcia, Spain
Prof. Duvvuru Gunasekar
Tirupati, India
Prof. A.A. Leslie Gunatilaka
Tucson, AZ, USA
Prof. Kurt Hostettmann
Lausanne, Switzerland
Prof. Martin A. Iglesias Arteaga
Mexico, D.F., Mexico
Prof. Jerzy Jaroszewski
Copenhagen, Denmark
Prof. Leopold Jirovetz
Vienna, Austria
Prof. Teodoro Kaufman
Rosario, Argentina
Prof. Norbert De Kimpe
Gent, Belgium

HONORARY EDITOR
PROFESSOR GERALD BLUNDEN
The School of Pharmacy & Biomedical Sciences,
University of Portsmouth,
Portsmouth, PO1 2DT U.K.
axuf64@dsl.pipex.com

INFORMATION FOR AUTHORS
Full details of how to submit a manuscript for publication in Natural Product Communications are given in Information for Authors on our Web site http://www.naturalproduct.us.

Authors may reproduce/republish portions of their published contribution without seeking permission from NPC, provided that any such republication is accompanied by an acknowledgment (original citation)-Reproduced by permission of Natural Product Communications. Any unauthorized reproduction, transmission or storage may result in either civil or criminal liability.

The publication of each of the articles contained herein is protected by copyright. Except as allowed under national “fair use” laws, copying is not permitted by any means or for any purpose, such as for distribution to any third party (whether by sale, loan, gift, or otherwise); as agent (express or implied) of any third party; for purposes of advertising or promotion; or to create collective or derivative works. Such permission requests, or other inquiries, should be addressed to the Natural Product Inc. (NPI). A photocopy license is available from the NPI for institutional subscribers that need to make multiple copies of single articles for internal study or research purposes.

To Subscribe: Natural Product Communications is a journal published monthly. 2010 subscription price: US$1,695 (Print, ISSN# 1934-578X); US$1,695 (Web edition, ISSN# 1555-9475); US$2,995 (Print + single site online); US$595 (Personal online). Orders should be addressed to Subscription Department, Natural Product Communications, Natural Product Inc., 7963 Anderson Park Lane, Westerville, Ohio 43081, USA. Subscriptions are renewed on an annual basis. Claims for nonreceipt of issues will be honored if made within three months of publication of the issue. All issues are dispatched by airmail throughout the world, excluding the USA and Canada.
Evaluation of Antiviral Activities of Curcumin Derivatives against HSV-1 in Vero Cell Line

Keivan Zandi*, Elissa Ramedani, Khosro Mohammadi, Saeed Tajbakhsh, Iman Deilamia, Zahra Rastian, Moradali Fouladvand, Forough Yousefi and Fatemeh Farshadpour

aThe Persian Gulf Marine Biotechnology Research Center, Bushehr University of Medical Sciences, Bushehr, Iran
bTropical Infectious Disease Research Center, Department of Medical Microbiology, Bushehr University of Medical Sciences, Bushehr, Iran
cThe Persian Gulf University, Faculty of Sciences, Department of Chemistry, Bushehr, Iran
dThe Persian Gulf Tropical and Infectious Disease Research Center, Bushehr University of Medical Sciences, Bushehr, Iran

zandi@bpums.ac.ir, keivanzandi@yahoo.com

Received: May 22nd, 2010; Accepted: September 28th, 2010

Antiviral drug resistance is one of the most common problems in medicine, and, therefore, finding new antiviral agents, especially from natural resources, seems to be necessary. This study was designed to assay the antiviral activity of curcumin and its new derivatives like gallium-curcumin and Cu-curcumin on replication of HSV-1 in cell culture. The research was performed as an *in vitro* study in which the antiviral activity of different concentrations of three substances including curcumin, Gallium-curcumin and Cu-curcumin were tested on HSV-1. The cytotoxicity of the tested compounds was also evaluated on the Vero cell line.

The CC50 values for curcumin, gallium-curcumin and Cu-curcumin were 484.2 µg/mL, 255.8 µg/mL and 326.6 µg/mL, respectively, and the respective IC50 values 33.0 µg/mL, 13.9 µg/mL and 23.1 µg/mL. The calculated SI values were 14.6, 18.4 and 14.1, respectively. The results showed that curcumin and its new derivatives have remarkable antiviral effects on HSV-1 in cell culture.

**Keywords:** Herpes simplex virus type 1 (HSV-1), curcumin, gallium-curcumin, Cu-curcumin, cell culture.

Viral diseases have always been a major health problem and scientists have continually tried to find new antiviral compounds. Cold sores, one of these viral diseases, are caused by herpes simplex virus type 1 (HSV-1), which is a DNA virus of the herpesviridae family [1].

Most complications caused by HSV-1 are self-limited, but HSV-1 can establish lifelong latent infection in sensory ganglia and some factors will cause the reactivation of the virus [2]. Herpes simplex virus-1 infection is common worldwide, with 45% to 98% of the world population being infected in different populations [1,2]. Due to the high prevalence of HSV-1 infections, several antiviral drugs have been developed for the treatment of HSV-1 infections, but many of them show severe side effects and are unable to cure the infections completely. Nearly all clinically effective antiviral drugs are nucleoside analogues. However, following a long period of their use, drug resistance has emerged [3]. Therefore, finding novel anti HSV-1 agents with low side effects is necessary. It has been suggested that natural products from plants can exhibit anti HSV-1 activities. Such natural products need to be isolated and screened for their potential to act as antiviral compounds [4]. One of these natural antiviral agents is curcumin, a major antioxidant compound and a principal constituent of the spice turmeric (*Curcuma longa*) [5], a native plant from south India and Indonesia. This spice has been used for hundreds of years for flavoring and coloring of many kinds of foods and is also used as a food preservative [6,7].

Regarding the use of turmeric in Indian and Chinese traditional medicine many scientists are interested to reveal the therapeutic and biological functions of this compound. Curcumin can affect the metabolism of cells and organisms [8]. Also, it has anti-tumor, antioxidant,
Table 1: Inhibition of HSV-1 related cytopathic effect (CPE) by using different concentrations of curcumin. Each value represents the mean of four replicate assays.

<table>
<thead>
<tr>
<th>Concentration (μg/mL)</th>
<th>CPE Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>24</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>36</td>
<td>55</td>
</tr>
<tr>
<td>42</td>
<td>75</td>
</tr>
<tr>
<td>48</td>
<td>90</td>
</tr>
<tr>
<td>54</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2: Inhibition of HSV-1 related cytopathic effect (CPE) by using different concentrations of gallium-curcumin. Each value represents the mean of four replicate assays.

<table>
<thead>
<tr>
<th>Concentration (μg/mL)</th>
<th>CPE Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>60</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>36</td>
<td>90</td>
</tr>
<tr>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3: Inhibition of HSV-1 related cytopathic effect (CPE) by using different concentrations of Cu-curcumin. Each value represents the mean of four replicate assays.

<table>
<thead>
<tr>
<th>Concentration (μg/mL)</th>
<th>CPE Inhibition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>60</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>36</td>
<td>90</td>
</tr>
<tr>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

Antiinflammatory, antiviral and anti-infectious properties [6,10,11,12]. Although various antiviral effects of curcumin have been reported, more studies are necessary to develop it as an alternative antiviral drug for HSV-1 treatment or for providing a template for the synthesis of new anti HSV-1 agents [13].

In this study, we evaluated the in vitro anti-HSV-1 activity of curcumin and its novel derivatives gallium-curcumin and Cu-curcumin. Based on our knowledge, there has been no study of the antiviral activity of these last two compounds.

The cytotoxicities of curcumin, gallium-curcumin and Cu-curcumin on Vero cells were determined by calculation of their CC50 values as 484.2, 255.8 and 326.6 μg/mL, respectively. Regarding the collected data for the antiviral activity of curcumin (Table 1), gallium-curcumin (Table 2), and Cu-curcumin (Table 3) against HSV-1 in cell culture, the IC50 values of these compounds, calculated using STATA software, were 33.0, 13.9 and 23.1 μg/mL, respectively. As shown in Tables 1, 2 and 3, 12 μg/mL of curcumin, 4 μg/mL gallium-curcumin and 8 μg/mL of Cu-curcumin could not prevent CPE presentation, which is related to HSV-1 replication in cell culture. However, 54 μg/mL of curcumin, 30 μg/mL of gallium-curcumin and 42 μg/mL of Cu-curcumin totally prevented viral CPE presentation.

Based on our knowledge, no research has been reported up to now on the activity of the new derivatives of curcumin, Cu-curcumin and gallium-curcumin against viruses, especially HSV-1.

Antibacterial activities of curcumin and curcuminoids have been reported [14]. Curcumin has also been shown to inhibit the growth of several types of viruses and malignant cells [15]. Curcumin can inhibit the expression of immediate early genes of HSV-1 [8], and also inhibit the activity of HIV-1 integrase, which is necessary for replication of this virus [16].

Various derivatives related to curcumin were synthesized and tested as inhibitors of the replication cycle of some viruses [17]. Synthetic modification of antiviral agents in order to improve either their antiviral activity or pharmacological properties is of interest [18]. Therefore, two new complexes, Cu-curcumin and gallium-curcumin, were chosen for the present study.

In this study, the CC50 values obtained showed that the cytotoxicity of curcumin is less than those of its new derivatives gallium- and copper-curcumins. Based on the differences in the CC50 values of gallium-curcumin and Cu-curcumin it could be concluded that the gallium compound was more cytotoxic than the copper one to Vero cells.

In most studies, DMSO showed antiviral and cytotoxic effects in vitro on different cell types [19]. Thus we tested the probable DMSO cytotoxic and virucidal effects in the current study. The concentration of DMSO used in our study was less than 2%, which is the lowest concentration for an antiviral effect; therefore we ignored the effect of DMSO in our study.

Based on the data obtained, it could be concluded that curcumin and its new derivatives exhibited in vitro anti-HSV-1 activities. Such agents could be developed either as anti HSV-1 compounds or provide a template for the synthesis of new anti HSV-1 agents. Our results can be considered as an early step in elucidating the molecular basis of the antiviral activities of curcumin. Future research is necessary to determine the possible in vivo anti-HSV-1 activity of curcumin and its related derivatives. Also, the mechanism(s) of action of these compounds should be revealed in future studies.

Experimental

Cell and virus: The African green monkey kidney cell line (Vero) was used as an appropriate cell line for
HSV-1 propagation. The cells were cultured using Dulbecco minimum essential medium (Gibco) containing 10% fetal bovine serum (Gibco). The antiviral activity assay was carried out on the KOS strain of HSV-1. The virus was propagated in Vero cells and the titer of propagated viral stock was firmed as TCID 50 mL⁻¹ by using Karber’s method. After titration, viral stock was dispensed in sterile tubes, which were stored at -70°C until the date of use.

**Preparation of curcumin and its derivatives:** Curcumin was purchased from Sigma, and the curcumin derivatives were prepared as previously described [20]. Dimethyl sulfoxide (DMSO) was used as the solvent for curcumin and its derivatives.

**Cytotoxicity assay:** Cytotoxicity values of all compounds were determined by culturing Vero cells for 96 h in the presence of increasing amounts of each substance. Three wells for each concentration of each compound were used. Viable cells were determined by the trypan blue exclusion test. Results were plotted as a dose response curve and 50% cell growth inhibitory concentration (CC₅₀) was obtained by using STATA modeling software.

**Antiviral activity assay:** The cytopathic inhibiton assay was used to determine the semi-quantitative antiviral activity of each test compound. Briefly, Vero cells were grown in a 96-well cell culture microplate (2×10³ cells/well). The cultured plates were incubated at 37°C in the presence of 5% CO₂ until the cells showed 80% confluency. Subsequently, the culture medium was removed from each well and 100 TCID₅₀ of virus suspension and different concentrations of curcumin and its derivatives from minimal to maximal non-cytotoxic concentrations were added to each well of the cell culture microplate. For each concentration of curcumin and its derivatives 4 wells were chosen.

For the virus control, 100 TCID₅₀ with the highest amount of DMSO which did not show cytotoxicity were added to 4 wells. Also, in each microplate, 4 wells were treated with DMSO without virus as a negative control for virus. In addition, 4 wells of each row were treated with the highest level of each curcumin based compound which did not previously exhibit cytotoxicity.

The plates were incubated at 37°C in a humidified CO₂ atmosphere (5% CO₂) and were investigated every day for cytopathic effect (CPE) presentation up to 5 days post infection.

The degree of inhibition was expressed as percent yield of virus control (% virus control = CPE experimental group/CPE virus control × 100). The concentration of each compound which reduced 50% of CPE presentation with respect to virus control was estimated from graphic plots defined as 50% inhibited concentration (IC₅₀) expressed in μg per mL by using STATA modeling software. The selectivity index (SI) was measured from the ratio of CC₅₀/IC₅₀ [21,22].

**Statistical analysis:** The STATA statistical analysis package was used for curve plotting in order to calculate IC₅₀ and CC₅₀ values.

**Acknowledgments** - The authors would like to thank DrvIraj Nabipour for his invaluable comments and Mr Rahim Tahmasebi for the statistical analysis of the data. Also, we express our gratitude to the Research Deputy of Bushehr University of Medical Sciences for the financial aid and funding.

**References**


Inhibition of Protein Tyrosine Phosphatase 1β by Hispidin Derivatives Isolated from the Fruiting Body of *Phellinus linteus*
Yeon Sil Lee, Il-Jun Kang, Moo Ho Won, Jae-Yong Lee, Jin Kyu Kim and Soon Sung Lim 1927

A New Azafluorenone from the Roots of *Polyalthia cerasoides* and its Biological Activity
Kanchana Pumsalid, Haruthai Thaisuchat, Chatchanok Loetchutinrat, Narong Nuntasaen, Puttinnan Meepowpan and Wilart Pompimon 1931

Evaluation of Antiviral Activities of Curcumin Derivatives against HSV-1 in Vero Cell Line
Keivan Zandi, Elissa Ramedani, Khosro Mohammadi, Saeed Tajbaksh, Iman Deilami, Zahra Rastian, Moradali Fouladvand, Forough Yousefi and Fatemeh Farshadpour 1935

Hyloglyceride and Hylodiglyceride: Two New Glyceride Derivatives from *Hylobdendron gabunensis*
Awazi Tengu Nyongha, Hidayat Hussain, Etienne Dongo, Ishtiaq Ahmed and Karsten Krohn 1939

Chemical Composition and Bioactivities of the Marine Alga *Isochrysis galbana* from Taiwan
Chi-Cheng Yu, Hsiao-Wei Chen, Mao-Jing Chen, Yu-Ching Chang, Shih-Chang Chien, Yueh-Hsiung Kuo, Feng-Ling Yang, Shih-Hsiung Wu, Jie Chen, Hsiao-Hui Yu and Louis Kuop-Ping Chao 1941

An Efficient Protocol for High-frequency Direct Multiple Shoot Regeneration from Internodes of Peppermint (*Mentha x piperita*)
Sanjog T. Thul and Arun K. Kukreja 1945

Essential Oil Yield and Chemical Composition Changes During Leaf Ontogeny of Palmarosa (*Cymbopogon martini* var. *motia*)
Bhaskaruni R. Rajeswara Rao, Dharmendra K. Rajput, Rajendra P. Patel and Somasi Pumanand 1947

Essential Oil Composition of Four Endemic *Ferula* Species Growing in Turkey
Ceyda Sibel Kilç, Ayşe Mine Gençler Özkan, Betül Demirci, Maksut Coşkun and Kemal Hüsnü Can Başer 1951

Essential Oils of *Daucus carota* subsp. *carota* of Tunisia Obtained by Supercritical Carbon Dioxide Extraction
Hanan Marzouki, Abdelhamid Khaldi, Danilo Falconieri, Alessandra Piras, Bruno Marongiu, Paola Molicotti and Stefania Zanetti 1955

Oil Constituents of *Artemisia nilagirica* var. *septentrionalis* Growing at Different Altitudes
Flora Haider, Narendra Kumar, Ali Arif Naqvi and Guru Das Bagchi 1959

Volatile Oil Composition of *Pogostemon heyneanus* and Comparison of its Composition with Patchouli Oil

Chemical Composition of Volatile Oils of *Aquilaria malaccensis* (Thymelaeaceae) from Malaysia
Saiful Nizam Tajuddin and Masitah M. Yusoff 1965

Chemical Composition and Phytotoxic Effects of Essential Oils from Four *Teucrium* Species
Laura De Martino, Carmen Formisano, Emilia Mancini, Vincenzo De Feo, Franco Piozzi, Daniela Rigano and Felice Senatore 1969

Chemical Constituents and Larvicidal Activity of *Hymenaea courbaril* Fruit Peel

Caryophyllene Oxide-rich Essential Oils of Lithuanian *Artemisia campestris* ssp. *campestris* and Their Toxicity
Asta Judzentiene, Jurga Budiene, Rita Butkiene, Eugenija Kupcinskiene, Isabelle Laffont-Schwob and Véronique Masotti 1981

Comparison of Antibacterial Activity of Natural and Hydroformylated Essential Oil of *Thymus capitatus* Growing Wild in North Sardinia with Commercial *Thymus* Essential Oils
Marianna Usai, Marzia Foddai, Barbara Sechi, Claudia Juliano and Mauro Marchetti 1985

Composition and Chemical Variability of the Leaf Oil from Corsican *Juniperus thurifera*
Integrated Analysis by GC(RI), GC-MS and 13C NMR
Josephine Ottavioli, Joseph Casanova and Ange Bigelli 1991

Combined Analysis by GC (RI), GC-MS and 13C NMR of the Supercritical Fluid Extract of *Abies alba* Twigs
Emilie Duquesnoy, Bruno Marongiu, Vincent Castola, Alessandra Piras, Silvia Porcedda and Joseph Casanova 1995

Review/Account
Eugenol: A Natural Compound with Versatile Pharmacological Actions
Kannisery Pramod, Shahid H. Ansari and Javed Ali 1999
Anticonvulsant Activity of the Linalool Enantiomers and Racemate: Investigation of Chiral Influence
Damião P. de Sousa, Franklin F. F. Nóbrega, Camila C. M. P. Santos and Reinaldo N. de Almeida 1847

Kinetic Analysis of Genipin Degradation in Aqueous Solution
Paul Slusarewicz, Keng Zhu and Tom Hedman 1853

Microbial Transformation of Marine Halogenated Sesquiterpenes
Aurelio San Martin, Juanita Rovirosa, Alvaro Carrasco, Silvia Orejarena, Jorge Soto-Delgado, Renato Contreras and M. Cristina Chamy 1859

Two New Guaianolides from Amberboa ramosa
Muhammad Ibrahim, Rehan Khan and Abdul Malik 1865

Antiplasmodial and Cytotoxic Activities of Drimane Sesquiterpenes from Canella winterana
Mary H. Grace, Carmen Lategan, Flaubert Mbeunkui, Rocky Graziose, Peter J. Smith, Ilya Raskin and Mary Ann Lila 1869

Three New 18-Oxygenated ent-Kaurane Diterpenoids from Isodon leucophyllus
Hai Bo Zhang, Jian Xin Pu, Yong Zhao, Fei He, Wei Zhao, Li Guang Lou, Wei Lie Xiao and Han Dong Sun 1873

Immunomodulatory Action of Monosulfated Triterpene Glycosides from the Sea Cucumber Cucumaria okhotensis: Stimulation of Activity of Mouse Peritoneal Macrophages
Dmitry L. Aminin, Alexandra S. Silchenko, Sergey A. Avilov, Vadim G. Stepanov and Vladimir I. Kalinin 1877

Three New Aaptamines from the Marine Sponge Aaptos sp. and Their Proapoptotic Properties
Larisa K. Shubina, Tatyana N. Makarieva, Sergey A. Dyshlovoy, Sergey N. Fedorov, Pavel S. Dmitrenok and Valentin A. Stonik 1881

Isolation and Characterization of Crotosparsamide, a New Cyclic Nonapeptide from Croton sparsiflorus
Rashad Mehmood and Abdul Malik 1885

Two New Lavandulyl Flavonoids from Sophora flavescens
Dan Liu, Xiulan Xin, Dong-hai Su, Junying Liu, Qing Wei, Bo Li and Jian Cui 1889

Biotransformation of Naringenin to Eriodictyol by Saccharomyces cerevisiae Functionally Expressing Flavonoid 3’ Hydroxylase
Ilef Limem-Ben Amor, Alain Hehn, Emmanuel Guedon, Kamel Ghedira, Jean-Marc Engasser, Leila Chekir-Ghedira and Mohamed Ghoul 1893

Two New 3-Carboxylated Flavones from the Rhizomes of Caragana conferta
Rehan Khan, Abdul Malik, Shazia Yasmeen and Nighat Afza 1899

Kaempferol Glycosides in the Flowers of Carnation and their Contribution to the Creamy White Flower Color
Tsukasa Iwashina, Masa-atsu Yamaguchi, Masayoshi Nakayama, Takashi Onozaki, Hiroyuki Yoshida, Shuji Kawanobu, Hiroshi Ono and Masachika Okamura 1903

Factors Influencing Glabridin Stability
Mingzhang Ao, Yue Shi, Yongming Cui, Wentao Guo, Jing Wang and Longjiang Yu 1907

Effect of Different Strains of Agrobacterium rhizogenes and Nature of Explants on Plumbago indica Hairy Root Culture with Special Emphasis on Root Biomass and Plumbagin Production
Moumita Gangopadhyay, Saikat Dewanjee, Somnath Bhattacharyya and Sabita Bhattacharya 1913

Fujianmycin C, A Bioactive Angucyclinone from a Marine Derived Streptomyces sp. B6219
Muna Ali Abdalla, Elisabeth Helmke and Hartmut Laatsch 1917

Dioscorealide B from the Traditional Thai Medicine Hua-Khao-Yen Induces Apoptosis in MCF-7 Human Breast Cancer Cells via Modulation of Bax, Bak and Bel-2 Protein Expression
Jirapon Saekoo, Potchanapond Graiet, Wilairat Leeansaksiri, Chavaboon Decksukum and Arunporn Itharat 1921

Continued inside backcover