

# CONTENTS

	<b>Page</b>
บทคัดย่อ	(3)
Abstract	(5)
Acknowledgement	(6)
Contents	(7)
List of Tables	(9)
List of Illustrations	(10)
Abbreviations and Symbols	(21)
1 Introduction	1
1.1 General Introduction	1
1.2 Introduction of <i>Verticillium</i>	2
1.3 Literature reviews: Bioactive compounds from <i>Verticillium</i>	3
2 Experimental	13
2.1 Chemicals and instruments	13
2.2 Fungal Material	13
2.3 Fermentation and extraction	14
2.4 Isolation	14
2.4.1 Purification of the extract from culture filtrate	15
2.4.2 Purification of the mycelia extract	19
2.5 Precursor-directed biosynthesis	25
2.5.1 Feeding experiments and HPLC analysis	25
2.5.2 Isolation from L-leucine-fed culture	27
2.5.3 Isolation from L-isoleucine-feeding culture	30
2.6 Biological assays	34
3 Results and discussion	35
3.1 Chemical constituents from broth extract of <i>Verticillium hemipterigenum</i> BCC 1449	35
	(7)

## CONTENTS (Continued)

	<b>Page</b>
3.1.1 Structure elucidation of compound <b>51</b>	36
3.1.2 Structure elucidation of compound <b>52</b>	40
3.1.3 Structure elucidation of compound <b>53</b> (pyrenocine A)	43
3.1.4 Structure elucidation of compound <b>54</b> (pyrenocine B)	46
3.1.5 Structure elucidation of compound <b>55</b> (enniatin B)	49
3.1.6 Structure elucidation of compound <b>56</b> (enniatin B <sub>4</sub> )	55
3.2 Chemical constituents from the cell extract of <i>Verticillium hemipterigenum</i> BCC 1449	59
3.2.1 Structure elucidation of compound <b>57</b> (enniatin H)	60
3.2.2. Structure elucidation of compound <b>58</b> (enniatin I)	65
3.3 Studies on precursor-directed biosynthesis using <i>Verticillium hemipterigenum</i> BCC 1449	70
3.3.1. Precursor-directed biosynthesis.	72
3.3.2 Structure elucidation of compound <b>59</b> (enniatin G)	77
3.3.3 Structure elucidation of compound <b>60</b> (enniatin C)	82
3.3.4 Structure elucidation of compound <b>61</b> (MK 1688)	86
3.4 Biological activities	90
Conclusion	92
Reference	93
Appendix	103
Publications	229
Vitae	230

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
<b>1</b>	Antifungal activities of bigutol and methylbigutol	4
<b>2</b>	Inhibitory effects of ES-242s on the binding of [ <sup>3</sup> H] TCP or [ <sup>3</sup> H] kainate	8
<b>3</b>	<i>In vitro</i> antimicrobial activity of compounds <b>25</b> , <b>26</b> , and <b>27</b>	9
<b>4</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>51</b>	39
<b>5</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>52</b> in CDCl <sub>3</sub>	42
<b>6</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>53</b> in CDCl <sub>3</sub>	45
<b>7</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>54</b> in CDCl <sub>3</sub>	48
<b>8</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>55</b>	52
<b>9</b>	<sup>1</sup> H and <sup>13</sup> C NMR data of compound <b>56</b>	57
<b>10</b>	NMR data for compound <b>57</b> in CDCl <sub>3</sub>	64
<b>11</b>	NMR data for compound <b>58</b> in CDCl <sub>3</sub>	69
<b>12</b>	Enniatin composition in extracts from precursor-feeding experiments	76
<b>13</b>	NMR data for compound <b>59</b> (enniatin G) in CDCl <sub>3</sub>	80
<b>14</b>	NMR data for compound <b>60</b> (enniatin C) in CDCl <sub>3</sub>	85
<b>15</b>	NMR data for compound <b>61</b> (MK 1688) in CDCl <sub>3</sub>	89
<b>16</b>	Antiplasmodial, antimycobacterial, and cytotoxic activities of enniatins <b>55-61</b>	91

## LIST OF ILLUSTRATIONS

Figure		Page
1	Extraction from <i>V. hemipterigenum</i> BCC 1449 culture	21
2	Isolation of compounds 51-56 from the filtrate extract	22
3	Isolation of compounds 55-58 from the mycelial extract	24
4	Extraction procedure in precursor-directed biosynthesis	26
5	Isolation of compounds 55, 56, 59, and 60 from the filtrate and mycelial extract of BCC 1449 + L-leucine	29
6	Extraction of <i>V. hemipterigenum</i> BCC 1449 culture + L-isoleucine	32
7	Isolation of compounds 55, 57, 58, and 61 from the filtrate and mycelial extract of BCC 1449 + L-leucine	33
8	Selected HMBC correlations for <b>51</b>	37
9	X-ray crystal structure of <b>51</b> and crystallographic data	38
10	Selected HMBC correlations for <b>52</b>	41
11	Selected HMBC correlations for <b>53</b>	44
12	Selected HMBC correlations for <b>54</b>	47
13	Selected HMBC correlations	50
14	The gross structure of compound <b>55</b>	51
15	NOESY spectrum of compound <b>55</b> (enniatin B) in CDCl <sub>3</sub>	54
16	Proton assignment for six residues	56
17	The gross structure of compound <b>57</b>	62
18	NOESY spectrum of compound <b>57</b>	63
19	Partial structures and NMR assignments for compound <b>58</b>	67
20	NOESY spectrum of compound <b>58</b>	68
21	Biosynthesis of enniatins	70
22	Precursors and possible residues in enniatins	71

## LIST OF ILLUSTRATIONS (Continued)

Figure	Page
23 HPLC chromatogram of the EtOAc extracts from culture filtrate (detection at 210 nm): (a) control (non-additive); (b) L-leucine fed (20 mM); (c) L-Isoleucine fed (20 mM). Internal standard (I.S.): ethyl 4-phenylbenzoate (0.50 mg)	73
24 HPLC chromatogram of the MeOH extracts from mycelia (detection at 210 nm): (a) control (non-additive); (b) L-leucine fed (20 mM); (c) L-Isoleucine fed (20 mM). Internal standard (I.S.): ethyl 4-phenylbenzoate (0.50 mg)	74
25 Enniatins from precursor-directed biosynthesis	75
26 Proton assignment for six residues	78
27 Proton assignment for two residues	83
28 The gross structure of compound <b>60</b>	84
29 Proton assignment for two residues	87
30 The gross structure of compound <b>61</b>	88
31 UV spectrum of compound <b>51</b>	104
32 IR spectrum of compound <b>51</b>	104
33 HRMS spectrum of compound <b>51</b>	105
34 <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	105
35 Expansion of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	106
36 <sup>1</sup> H NMR (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	106
37 Expansion of <sup>1</sup> H NMR (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	107
38 <sup>13</sup> C NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	107
39 Expansion A of <sup>13</sup> C NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	108
40 Expansion B of <sup>13</sup> C NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	108
41 Expansion C of <sup>13</sup> C NMR (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	109
42 <sup>13</sup> C NMR (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	109
43 Expansion of <sup>13</sup> C NMR (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	110
44 DEPT 45 (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	110

## LIST OF ILLUSTRATIONS (Continued)

Figure		Page
45	DEPT 90 (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	111
46	DEPT 135 (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	111
47	HMQC (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	112
48	Expansion A of HMQC (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	112
49	Expansion B of HMQC (MeOH- <i>d</i> <sub>4</sub> ) spectrum of compound <b>51</b>	113
50	COSY (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	113
51	Expansion A of COSY (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	114
52	Expansion B of COSY (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	114
53	HMBC (MeOH- <i>d</i> <sub>4</sub> , d <sub>6</sub> =110 msec) spectrum of compound <b>51</b>	115
54	Expansion A of HMBC (MeOH- <i>d</i> <sub>4</sub> , d <sub>6</sub> =110 msec) spectrum of compound <b>51</b>	115
55	Expansion B of HMBC (MeOH- <i>d</i> <sub>4</sub> , d <sub>6</sub> =110 msec) spectrum of compound <b>51</b>	116
56	Expansion C of HMBC (MeOH- <i>d</i> <sub>4</sub> , d <sub>6</sub> =110 msec) spectrum of compound <b>51</b>	116
57	HMBC (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	117
58	Expansion A of HMBC (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	117
59	Expansion B of HMBC (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	118
60	Expansion C of HMBC (CDCl <sub>3</sub> ) spectrum of compound <b>51</b>	118
61	UV spectrum of compound <b>52</b>	119
62	IR spectrum of compound <b>52</b>	119
63	HRMS spectrum of compound <b>52</b>	120
64	<sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of compound <b>52</b>	120
65	Expansion of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of compound <b>52</b>	121
66	<sup>13</sup> C NMR spectrum of compound <b>52</b>	121
67	DEPT 135 spectrum of compound <b>52</b>	122
68	HMQC spectrum of compound <b>52</b>	122
69	Expansion A of HMQC spectrum of compound <b>52</b>	123
70	Expansion B of HMQC spectrum of compound <b>52</b>	123

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>		<b>Page</b>
71	COSY spectrum of compound <b>52</b>	124
72	HMBC spectrum (d6=50 msec) of compound <b>52</b>	124
73	Expansion A of HMBC spectrum (d6=50 msec) of compound <b>52</b>	125
74	Expansion B of HMBC spectrum (d6=50 msec) of compound <b>52</b>	125
75	Expansion C of HMBC spectrum (d6=50 msec) of compound <b>52</b>	126
76	HMBC spectrum (d6=100 msec) of compound <b>52</b>	126
77	Expansion A of HMBC spectrum (d6=100 msec) of compound <b>52</b>	127
78	Expansion B of HMBC spectrum (d6=100 msec) of compound <b>52</b>	127
79	Expansion C of HMBC spectrum (d6=100 msec) of compound <b>52</b>	128
80	Expansion D of HMBC spectrum (d6=100 msec) of compound <b>52</b>	128
81	UV spectrum of pyrenocine A ( <b>53</b> )	129
82	IR spectrum of pyrenocine A ( <b>53</b> )	129
83	EIMS spectrum of pyrenocine A ( <b>53</b> )	130
84	<sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of pyrenocine A ( <b>53</b> )	130
85	Expansion of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) of pyrenocine A ( <b>53</b> )	131
86	<sup>13</sup> C-NMR spectrum of pyrenocine A ( <b>53</b> )	131
87	DEPT 45 spectrum of pyrenocine A ( <b>53</b> )	132
88	DEPT 90 spectrum of pyrenocine A ( <b>53</b> )	132
89	DEPT 135 spectrum of pyrenocine A ( <b>53</b> )	133
90	HMQC spectrum of pyrenocine A ( <b>53</b> )	133
91	Expansion of HMQC spectrum of pyrenocine A ( <b>53</b> )	134
92	HMBC spectrum (d6 = 100 msec) of pyrenocine A ( <b>53</b> )	134
93	Expansion A of HMBC spectrum (d6 = 100 msec) of pyrenocine A ( <b>53</b> )	135
94	Expansion B of HMBC spectrum (d6 = 100 msec) of pyrenocine A ( <b>53</b> )	135
95	Expansion C of HMBC spectrum (d6 = 100 msec) of pyrenocine A ( <b>53</b> )	136
96	Expansion D of HMBC spectrum (d6 = 100 msec) of pyrenocine A ( <b>53</b> )	136

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>		<b>Page</b>
97	UV spectrum of pyrenocine B (54)	137
98	IR spectrum of pyrenocine B (54)	137
99	EIMS spectrum of pyrenocine B (54)	138
100	<sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of pyrenocine B (54)	138
101	Expansion A of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of pyrenocine B (54)	139
102	Expansion B of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of pyrenocine B (54)	139
103	<sup>13</sup> C-NMR (CDCl <sub>3</sub> ) spectrum of pyrenocine B (54)	140
104	HMQC spectrum of pyrenocine B (54)	140
105	Expansion of HMQC spectrum of pyrenocine B (54)	141
106	COSY spectrum of pyrenocine B (54)	141
107	Expansion of COSY spectrum of pyrenocine B (54)	142
108	HMBC spectrum of pyrenocine B (54)	142
109	Expansion of HMBC spectrum of pyrenocine B (54)	143
110	UV spectrum of enniatin B (55)	144
111	IR spectrum of enniatin B (55)	144
112	EIMS spectrum of enniatin B (55)	145
113	<sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of enniatin B (55)	145
114	Expansion of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of enniatin B (55)	146
115	<sup>13</sup> C-NMR spectrum of enniatin B (55)	146
116	DEPT 45 spectrum of enniatin B (55)	147
117	DEPT 90 spectrum of enniatin B (55)	147
118	DEPT 135 spectrum of enniatin B (55)	148
119	HMQC spectrum of enniatin B (55)	148
120	Expansion of HMQC spectrum of enniatin B (55)	149
121	COSY spectrum of enniatin B (55)	149
122	NOESY spectrum of enniatin B (55)	150



## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>	<b>Page</b>	
123	HMBC spectrum of enniatin B (55)	150
124	Expansion A of HMBC spectrum of enniatin B (55)	151
125	Expansion B of HMBC spectrum of enniatin B (55)	151
126	Expansion C of HMBC spectrum of enniatin B (55)	152
127	UV spectrum of enniatin B <sub>4</sub> (56)	153
128	IR spectrum of enniatin B <sub>4</sub> (56)	153
129	EIMS spectrum of enniatin B <sub>4</sub> (56)	154
130	<sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin B <sub>4</sub> (56)	154
131	Expansion A of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin B <sub>4</sub> (56)	155
132	Expansion B of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin B <sub>4</sub> (56)	155
133	<sup>13</sup> C NMR spectrum of enniatin B <sub>4</sub> (56)	156
134	Expansion A of <sup>13</sup> C NMR spectrum of enniatin B <sub>4</sub> (56)	156
135	Expansion B of <sup>13</sup> C NMR spectrum of enniatin B <sub>4</sub> (56)	157
136	Expansion C of <sup>13</sup> C NMR spectrum of enniatin B <sub>4</sub> (56)	157
137	DEPT 135 spectrum of enniatin B <sub>4</sub> (56)	158
138	COSY spectrum of enniatin B <sub>4</sub> (56)	158
139	UV spectrum of enniatin H (57)	159
140	IR spectrum of enniatin H (57)	159
141	HRMS spectrum of enniatin H (57)	160
142	<sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin H (57)	160
143	Expansion A of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin H (57)	161
144	Expansion B of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin H (57)	161
145	<sup>13</sup> C NMR spectrum of enniatin H (57)	162
146	Expansion A of <sup>13</sup> C NMR spectrum of enniatin H (57)	162
147	Expansion B of <sup>13</sup> C NMR spectrum of enniatin H (57)	163
148	Expansion C of <sup>13</sup> C NMR spectrum of enniatin H (57)	163

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>	<b>Page</b>
149 Expansion D of $^{13}\text{C}$ NMR spectrum of enniatin H (57)	164
150 DEPT 135 spectrum of enniatin H (57)	164
151 Expansion A of DEPT 135 spectrum of enniatin H (57)	165
152 Expansion B of DEPT 135 spectrum of enniatin H (57)	165
153 HMQC spectrum of enniatin H (57)	166
154 Expansion A of HMQC spectrum of enniatin H (57)	166
155 Expansion B of HMQC spectrum of enniatin H (57)	167
156 Expansion C of HMQC spectrum of enniatin H (57)	167
157 Expansion D of HMQC spectrum of enniatin H (57)	168
158 COSY spectrum of enniatin H (57)	168
159 NOESY spectrum of enniatin H (57)	169
160 HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	169
161 Expansion A of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	170
162 Expansion B of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	170
163 Expansion C of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	171
164 Expansion D of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	171
165 Expansion E of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	172
166 Expansion F of HMBC ( $d_6 = 100$ msec) spectrum of enniatin H (57)	172
167 UV spectrum of enniatin I (58)	173
168 IR spectrum of enniatin I (58)	173
169 HRMS spectrum of enniatin I (58)	174
170 $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin I (58)	174
171 Expansion A of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin I (58)	175
172 Expansion B of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin I (58)	175
173 Expansion C of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin I (58)	176
174 Expansion A of $^{13}\text{C}$ NMR spectrum of enniatin I (58)	176

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>		<b>Page</b>
175	Expansion B of $^{13}\text{C}$ NMR spectrum of enniatin I (58)	177
176	Expansion C of $^{13}\text{C}$ NMR spectrum of enniatin I (58)	177
177	Expansion D of $^{13}\text{C}$ NMR spectrum of enniatin I (58)	178
178	DEPT 135 spectrum of enniatin I (58)	178
179	Expansion of DEPT 135 spectrum of enniatin I (58)	179
180	HMQC spectrum of enniatin I (58)	179
181	Expansion A of HMQC spectrum of enniatin I (58)	180
182	Expansion B of HMQC spectrum of enniatin I (58)	180
183	COSY spectrum of enniatin I (58)	181
184	Expansion of COSY spectrum of enniatin I (58)	181
185	NOESY spectrum of enniatin I (58)	182
186	Expansion A of NOESY spectrum of enniatin I (58)	182
187	Expansion B of NOESY spectrum of enniatin I (58)	183
188	Expansion C of NOESY spectrum of enniatin I (58)	183
189	Expansion D of NOESY spectrum of enniatin I (58)	184
190	HMBC spectrum of enniatin I (58)	184
191	Expansion A of HMBC spectrum of enniatin I (58)	185
192	Expansion B of HMBC spectrum of enniatin I (58)	185
193	Expansion C of HMBC spectrum of enniatin I (58)	186
194	Expansion D of HMBC spectrum of enniatin I (58)	186
195	UV spectrum of enniatin G (59)	187
196	IR spectrum of enniatin G (59)	187
197	HRMS spectrum of enniatin G (59)	188
198	$^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin G (59)	188
199	Expansion A of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin G (59)	189
200	Expansion B of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin G (59)	189

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>		<b>Page</b>
201	Expansion C of $^1\text{H}$ NMR ( $\text{CDCl}_3$ ) spectrum of enniatin G (59)	190
202	$^{13}\text{C}$ NMR spectrum of enniatin G (59)	190
203	Expansion A of $^{13}\text{C}$ NMR spectrum of enniatin G (59)	191
204	Expansion B of $^{13}\text{C}$ NMR spectrum of enniatin G (59)	191
205	Expansion C of $^{13}\text{C}$ NMR spectrum of enniatin G (59)	192
206	Expansion D of $^{13}\text{C}$ NMR spectrum of enniatin G (59)	192
207	Expansion E of $^{13}\text{C}$ NMR spectrum of enniatin G (59)	193
208	DEPT 135 spectrum of enniatin G (59)	193
209	Expansion of DEPT 135 spectrum of enniatin G (59)	194
210	HMQC spectrum of enniatin G (59)	194
211	Expansion A of HMQC spectrum of enniatin G (59)	195
212	Expansion B of HMQC spectrum of enniatin G (59)	195
213	Expansion C of HMQC spectrum of enniatin G (59)	196
214	COSY spectrum of enniatin G (59)	196
215	Expansion A of COSY spectrum of enniatin G (59)	197
216	Expansion B of COSY spectrum of enniatin G (59)	197
217	Expansion C of COSY spectrum of enniatin G (59)	198
218	NOESY spectrum of enniatin G (59)	198
219	Expansion A of NOESY spectrum of enniatin G (59)	199
220	Expansion B of NOESY spectrum of enniatin G (59)	199
221	Expansion C of NOESY spectrum of enniatin G (59)	200
222	Expansion D of NOESY spectrum of enniatin G (59)	200
223	Expansion E of NOESY spectrum of enniatin G (59)	201
224	Expansion F of NOESY spectrum of enniatin G (59)	201
225	HMBC spectrum of enniatin G (59)	202
226	Expansion A of HMBC spectrum of enniatin G (59)	202

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>	<b>Page</b>
227 Expansion B of HMBC spectrum of enniatin G (59)	203
228 Expansion C of HMBC spectrum of enniatin G (59)	203
229 Expansion D of HMBC spectrum of enniatin G (59)	204
230 Expansion E of HMBC spectrum of enniatin G (59)	204
231 Expansion F of HMBC spectrum of enniatin G (59)	205
232 Expansion G of HMBC spectrum of enniatin G (59)	205
233 Expansion H of HMBC spectrum of enniatin G (59)	206
234 Expansion I of HMBC spectrum of enniatin G (59)	206
235 UV spectrum of enniatin C (60)	207
236 IR spectrum of enniatin C (60)	207
237 HRMS spectrum of enniatin C (60)	208
238 <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin C (60)	208
239 Expansion A of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin C (60)	209
240 Expansion B of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin C (60)	209
241 Expansion C of <sup>1</sup> H NMR (CDCl <sub>3</sub> ) spectrum of enniatin C (60)	210
242 <sup>13</sup> C NMR spectrum of enniatin C (60)	210
243 Expansion A of <sup>13</sup> C NMR spectrum of enniatin C (60)	211
244 Expansion B of <sup>13</sup> C NMR spectrum of enniatin C (60)	211
245 Expansion C of <sup>13</sup> C NMR spectrum of enniatin C (60)	212
246 HMQC spectrum of enniatin C (60)	212
247 Expansion of HMQC spectrum of enniatin C (60)	213
248 COSY spectrum of enniatin C (60)	213
249 Expansion A of COSY spectrum of enniatin C (60)	214
250 Expansion B of COSY spectrum of enniatin C (60)	214
251 NOESY spectrum of enniatin C (60)	215
252 Expansion A of NOESY spectrum of enniatin C (60)	215

## LIST OF ILLUSTRATIONS (Continued)

<b>Figure</b>		<b>Page</b>
253	Expansion B of NOESY spectrum of enniatin C (60)	216
254	Expansion C of NOESY spectrum of enniatin C (60)	216
255	HMBC spectrum of enniatin C (60)	217
256	Expansion A of HMBC spectrum of enniatin C (60)	217
257	Expansion B of HMBC spectrum of enniatin C (60)	218
258	Expansion C of HMBC spectrum of enniatin C (60)	218
259	Expansion D of HMBC spectrum of enniatin C (60)	219
260	UV spectrum of MK 1688 (61)	220
261	IR spectrum of MK 1688 (61)	220
262	HRMS spectrum of MK 1688 (61)	221
263	<sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of MK 1688 (61)	221
264	Expansion A of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of MK 1688 (61)	222
265	Expansion B of <sup>1</sup> H-NMR (CDCl <sub>3</sub> ) spectrum of MK 1688 (61)	222
266	<sup>13</sup> C-NMR spectrum of MK 1688 (61)	223
267	DEPT 135 spectrum of MK 1688 (61)	223
268	HMQC spectrum of MK 1688 (61)	224
269	Expansion of HMQC spectrum of MK 1688 (61)	224
270	COSY spectrum of MK 1688 (61)	225
271	Expansion A of COSY spectrum of MK 1688 (61)	225
272	Expansion B of COSY spectrum of MK 1688 (61)	226
273	NOESY spectrum of MK 1688 (61)	226
274	Expansion of NOESY spectrum of MK 1688 (61)	227
275	HMBC spectrum of MK 1688 (61)	227
276	Expansion A of HMBC spectrum of MK 1688 (61)	228
277	Expansion B of HMBC spectrum of MK 1688 (61)	228

## ABBREVIATIONS AND SYMBOLS

brd	broad doublet (spectral)
brs	broad singlet (spectral)
°C	degree Celsius
CDCl <sub>3</sub>	deuterated chloroform
COSY	correlation spectroscopy
calcd.	calculated
cm <sup>-1</sup>	reciprocal centimeter (wave number unit)
D	dextrorotatory
DEPT	distortionless enhancement by polarization transfer
d	doublet (spectral)
dd	doublet of doublet (spectral)
1D NMR	one Dimensional Nuclear Magnetic Resonance
2D NMR	two Dimensional Nuclear Magnetic Resonance
EIMS	electron impact mass spectroscopy
ESI-TOF	electrospray ionization-time of flight
EtOAc	ethyl acetate
EtOH	ethanol
g	gram
HMBC	heteronuclear multiple bond correlation
HMQC	heteronuclear multiple quantum coherence
HPLC	high performance liquid chromatography
HRMS	high resolution mass spectroscopy
Hz	Hertz
H <sub>2</sub> O	water
IR	infrared
IC <sub>50</sub>	50% inhibitory concentration
<i>i</i> -Bu	<i>iso</i> -butyl group

## ABBREVIATIONS AND SYMBOLS (Continued)

<i>i</i> -Pr	<i>iso</i> -propyl group
<i>J</i>	coupling constant
L	levorotatory
MIC	minimum inhibitory concentration
MHz	megahertz
MS	mass spectroscopy
Me	methyl group
MeOH	methanol
MeOH- <i>d</i> <sub>4</sub>	deuterated methanol
MeCN	acetonitrile
m	multiplet (spectral)
mg	milligram
mL	millilitre
min	minute
mult	multiplicity
<i>m/z</i>	a value of mass divided by charge
NMR	nuclear magnetic resonance
NOESY	nuclear overhauser effect spectroscopy
nM	nanomolar
nm	nanometer
PDA	potato dextrose agar
ppm	part per million
q	quartet (spectral)
rpm	round per minute
s	singlet (spectral)
TMS	tetramethylsilane
t	triplet (spectral)



## ABBREVIATIONS AND SYMBOLS (Continued)

UV	ultraviolet radiation
$\mu\text{g}$	microgram
$\mu\text{M}$	micromolar
$\nu$	absorption frequencies (wave number)
$\delta$	chemical shift (ppm)
$[\alpha]_{\text{D}}$	specific rotation
$\lambda_{\text{max}}$	maximum wavelength