Tropical Journal of Pharmaceutical Research April 2014; 13 (4): 635-648
ISSN: 1596-5996 (print); 1596-9827 (electronic)

Available online at http://www.tjpr.org
http://dx.doi.org/10.4314/tjpr.v13i4.23

Review Article

Phytochemical and Pharmacological Studies of the Genus *Tacca*: A Review

Jin-He Jiang[1,2], Hong-Mei Yang[1], Yi-Liang Wang[2] and Ye-Gao Chen[1]*
[1]Department of Chemistry, [2]Department of Library, Yunnan Normal University, Kunming 650500, PR China

For correspondence: **Email: jinhejiang@126.com, ygchen48@gmail.com*

Received: 5 April 2013 *Revised accepted: 6 February 2014*

Abstract

Tacca is an important genus comprising of approximately 15 species of the medicinal plants (Taccaceae). The plants are used in traditional medicine to relieve pains of the body and stomach, as an antidote for food poisoning as well as for their analgesic, antipyretic and anti-inflammatory activities. Chemical studies have underlined more than 120 constituents have been isolated from Tacca, including steroidals, diarylheptanoids, phenolics, flavonoids, sesquitepenoids, triterpenoids and starch. Steroidals and diarylheptanoids showed potent bioactivities, such as cytotoxic, microtubule-stabilizing, NF-κB activation and PPAR transcriptional and insecticidal activities. The starch from T. leontopetaloides and T. involucrata have high amylase content and showed potential use in food and drug system.

Keywords: *Tacca, Taccalonolides, Tacca starch, Microtubule-stabilizer, Anti-cancer*

Tropical Journal of Pharmaceutical Research is indexed by Science Citation Index (SciSearch), Scopus, International Pharmaceutical Abstract, Chemical Abstracts, Embase, Index Copernicus, EBSCO, African Index Medicus, JournalSeek, Journal Citation Reports/Science Edition, Directory of Open Access Journals (DOAJ), African Journal Online, Bioline International, Open-J-Gate and Pharmacy Abstracts

INTRODUCTION

Tacca comprises of approximately 15 species of acaulescent forest understory herbs and is included in the family Taccaceae. With Southeast Asia as their current distribution center, such species are primarily paleotropical in distribution with 6 occurring in China [1,2]. *T. chantriers* Andre is an indigenous perennial in the tropics which is used by local healers to relieve pains of the body and stomach, and as an antidote for food poisoning as well. Keardrit *et al* found it showed analgesic, antipyretic and anti-inflammatory activities as claimed in traditional medicine [3]. In China, its rhizome has been used in Chinese medicines for the treatment of various diseases including high blood pressure, burns, gastric ulcers, enteritis, and hepatitis [4].

T. integrifolia is mutagenic and its combined extracts from the medicinal plants are highly cytotoxic to the human cell lines, Hep2 and HFL1 [5]. Kitjaroennirut *et al* found that the hypotensive and negative chronotropic effect of *Tacca* extracts exists in rat [6].

In the early 1960s Professor Paul Scheuer investigated the “bitter principle” of the tubers of *T. leontopetaloides*, a starchy food source. Scheuer and his colleagues purified a compound they named taccalin in 1963 as an intensely bitter, light yellow powder with a probable tetracyclic structure [7]. The actual structure of taccalonolides was later found to be much larger, and this pioneering work laid groundwork for the elucidation of their structures in 1987. Then, much attention has been paid to *Tacca* species due to their cytotoxic, microtubule-stabilizing activities and as a starch source. The potency of taccalonolides, withanolides and their direct interaction with tubulin, together with their previous *in vivo* antitumor activities, reveal the

potential of taccalonolides as new anticancer agents [8-12].

In this survey, we have explored the phytochemistry and pharmacological activities of the *Tacca* species in order to collate existing information on these plants as well as highlight its multi-activity properties as a medicinal agent and a potential source of industrial starch.

PHYTOCHEMICAL CONSTITUENTS

The chemical constituents of *Tacca* include steroidals, diarylheptanoids and their glucosides, terpenoids, flavonoids, and some other compounds [12-53]. By February 2013, their structures are shown below (compounds 1-122), and their names and the corresponding plant sources are collated in Table 1-8. Of all these compounds, one hundred steroidals are the predominant constituents have been isolated from the Genus *Tacca* [12-51].

Steroidals

Taccalonolides

Taccalonolides are a new class of plant-derived natural steroids with a microtubule-stabilizing activity. In 1987, two new steroidal bitter principles, taccalonolides A (1) and B (2), were isolated from a Chinese medicinal plant *T. plantaginea* [13]. Then Chen and his group first elucidated their complete structures with modern chemical techniques [14, 15]. Extensive studies of the Genus *Tacca* have led to the identification of taccalonolides C-Z (3-26), AA-AJ (27-33) and H2 (34) (Table 1, Fig 1) [8, 12-27]. All of them were new constituents and have antitumor activities. Taccalonolide AJ (33), an epoxidation product of taccalonolide B, was generated in semisynthesis. Each taccalonolide molecule contains a C (2)-C (3) epoxide, and all except six compounds [taccalonolide C (3), O-Q (15-17), X (24) and Y (25)] have a C (23)-C (26) lactone ring. To the best of our knowledge, taccasuboside A (35) is the first pentacyclic sterol glycoside with 6-6-6-5-6 fused rings [28].

Table 1: Taccalonolides from the genus *Tacca*

No.	Compound name	Species	Ref
1	Taccalonolide A	*T. chantriers,T.paxiana,T. plantaainea*	8,12-22
2	Taccalonolide B	*T. paxiana,T. plantaainea*	12-16,22
3	Taccalonolide C	*T. plantaainea*	16
4	Taccalonolide D	*T. plantaainea*	16
5	Taccalonolide E	*T. chantriers, T. paxiana, T. plantaainea*	8,20-23
6	Taccalonolide F	*T. plantaainea*	19,23
7	Taccalonolide G	*T. plantaainea*	17,23
8	Taccalonolide H	*T. plantaainea*	12,17,23
9	Taccalonolide I	*T. plantaainea*	17,23
10	Taccalonolide J	*T. plantaainea*	17,23
11	Taccalonolide K	*T. paxiana,T. plantaainea*	17,22,23
12	Taccalonolide L	*T. plantaainea*	23,24
13	Taccalonolide M	*T. plantaainea*	23,24
14	Taccalonolide N	*T. paxiana*	22
15	Taccalonolide O	*T. chantriers,T. subflabellata*	25-27
16	Taccalonolide P	*T. chantriers,T. subflabellata*	25-27
17	Taccalonolide Q	*T. subflabellata*	25
18	Taccalonolide R	*T. chantriers,T. paxiana*	21,22
19	Taccalonolide S	*T. paxiana*	22
20	Taccalonolide T	*T. chantriers,T. paxiana*	21,22
21	Taccalonolide U	*T. paxiana*	22
22	Taccalonolide V	*T. paxiana*	22
23	Taccalonolide W	*T. plantaainea*	18
24	Taccalonolide X	*T. plantaainea*	18
25	Taccalonolide Y	*T. plantaainea*	18
26	Taccalonolide Z	*T. integrifolia*	21
27	Taccalonolide AA	*T. chantriers*	21
28	Taccalonolide AB	*T. chantriers*	21
29	Taccalonolide AC	*T. plantaainea*	12
30	Taccalonolide AD	*T. plantaainea*	12
31	Taccalonolide AE	*T. plantaainea*	12
32	Taccalonolide AF	*T. plantaainea*	12
33	Taccalonolide AJ	*T. plantaainea*	12
34	Taccalonolide H2	*T. plantaainea*	12
35	Taccasuboside A	*T. subflabellata*	28

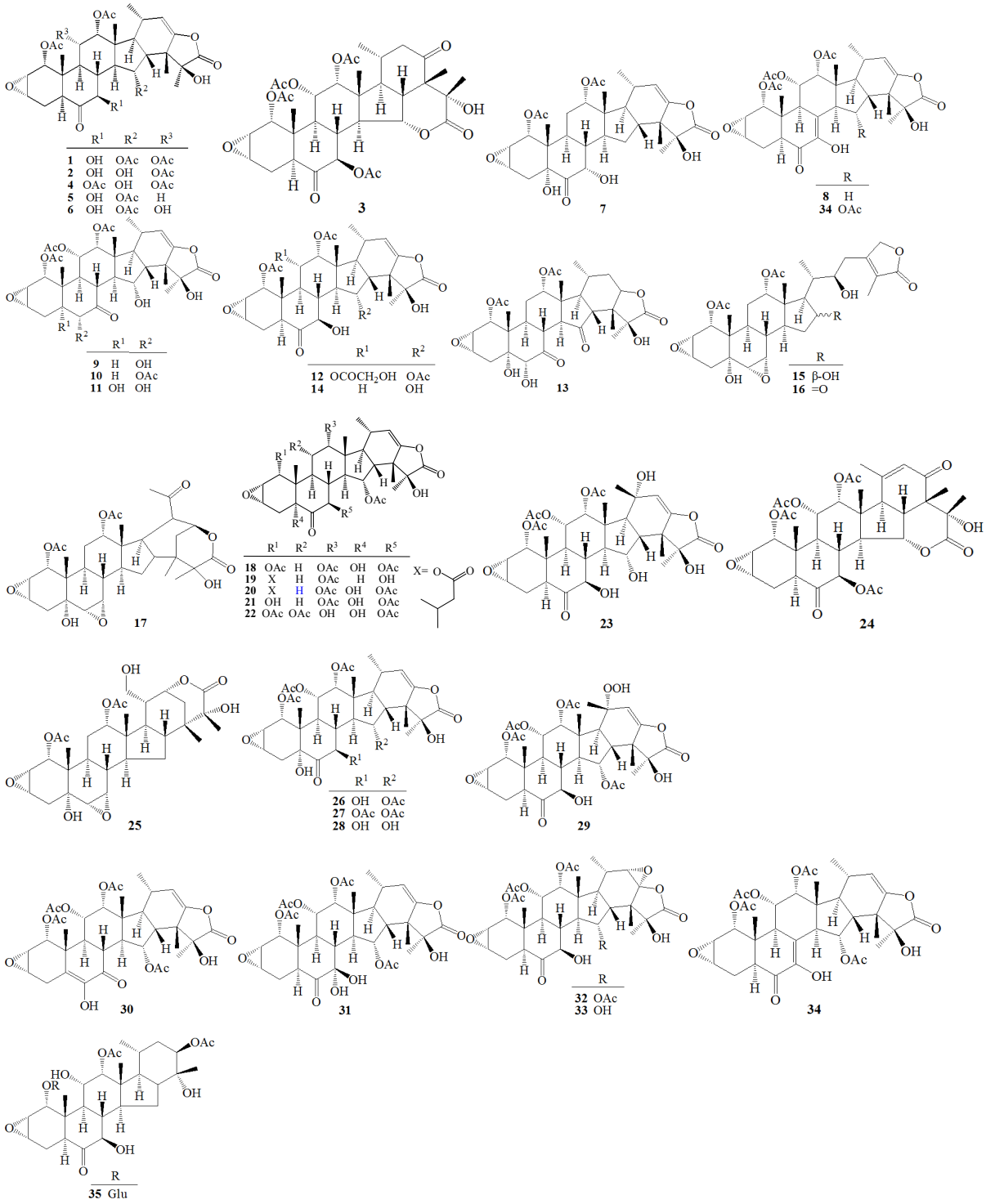

Fig 1: Structures of taccalonolides from *Tacca spps*

Withanolides and their glucosides

Six new withanolides named plantagiolide A-F (36-41), together with four withanolide glucosides (42-47) (Table 2, Fig 2) were isolated from the whole plants of *T. plantaainea* and *T. chantriers*, respectively [28-32]. The withanolides are a group of naturally occurring C28 steroids based on an ergostane skeleton in which C (26) and C (22), or C (26) and C (23), are oxidized in order to form a γ- or δ- lactone. Also, C-1 is easily oxidized to form a 1-oxosteroids. Interestingly, investigation of the extracts of *T. plantaainea* resulted in the isolation of plantagiolide I (46), an uncommon 3α-chloride withanolide glucoside. The origin of the chlorine atom has been attributed to the presence of NaCl in the plant [9]. Up to February 2013, no 3-chloro-5-hydroxyl-

Table 2: Withanolides and their glucosides from the genus *Tacca*

No.	Compound name	Species	Ref
36	Plantagiolide A	*T. plantaainea,T. subflabellata*	28,29
37	Plantagiolide B	*T. plantaainea*	29
38	Plantagiolide C	*T. plantaainea*	29
39	Plantagiolide D	*T. plantaainea*	29
40	Plantagiolide E	*T. plantaainea*	29
41	Plantagiolide F	*T. plantaainea*	30
42	Chantriolide A	*T. chantriers,T. plantaainea, T. subflabellata*	27-29, 31,32
43	Chantriolide B	*T. chantriers,T. subflabellata, T. plantaainea*	28,31,32
44	Chantriolide C	*T. chantriers*	27
45	Plantagiolide I	*T. plantaainea*	31
46	Plantagiolide J	*T. plantaainea*	31
47	(22*R**,24*R**,25*S*)-3*β*-[(*O*-*β*-D-Glucopyranosyl)-(1→4)-O-*β*-D-glucopyranosyl-(1→2)-O-[*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)oxy] -22-hydroxyergost -5-en-26-oic acid *δ*-latone	*T. chantriers*	33

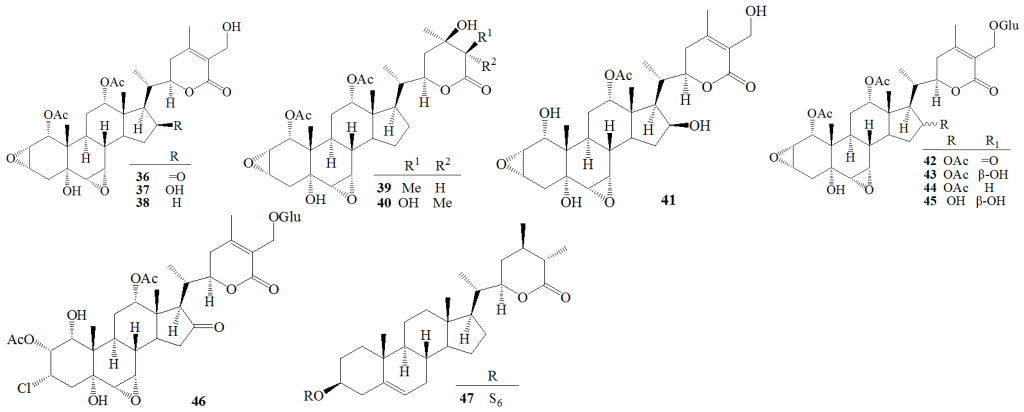

Fig 2: Structures of withanolides and their glucosides from genus *Tacca*

Table 3: Cholestan saponins from *T. chantriers*

No.	Compound name	Ref
48	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl)-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*O*-[*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)-oxy] ergost-5- en-3*β*-yl *O*-*β*-D-glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)]-*β*-D-glucopyranoside	33
49	Taccasteroside A	34
50	Taccasteroside B	34
51	Taccasteroside C	34
52	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranoside	35
53	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranoside	35
54	(24*R*,25*S*)-3*β*-Hydroxyergost-5-en-26-yl *O*-*β*-D-glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranoside	35
55	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*O*-[*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranoside	35
56	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*β*-D-glucopyranosyl-(1→6)]-*β*-*D*-glucopyranosyl) oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranside	35
57	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→3)-*O*-[*O*-*β*-D-glucopyranosyl -(1→4)-*β*-D-glucopyranosyl-(1→6)]-*β*-D-glucopyranosyl)oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranoside	35
58	(24*R*,25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→4)-*O*-*β*-D-glucopyranosyl-(1→2)-*β*-D-glucopyranosyl)oxy]ergost-5-en-3*β*-yl *β*-D-glucopyranoside	35

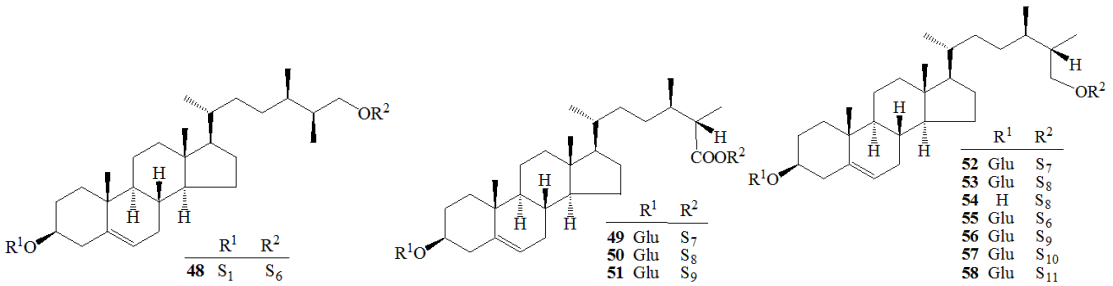

Fig 3: Structures of cholestan saponins from *T. chantriers*

Table 4: Spirostanol saponins from the genus *Tacca*

No.	Compound name	Species	Ref
59	Leontogenin (25*R*)-B-nor(7)-6*β*-formyl-spirostane-3*β*,5*β*-diol	*T. leontopetaloides*	36
60	(25*R*)- and (25*S*)-spirotaccagenins	*T. leontopetaloides*	37
61	Diosgenin	*T. leontopetaloides*	38
62	Isonuatigenin	*T. leontopetaloides*	38
63	Isonarthogenin	*T. leontopetaloides*	38
64	(25*S*)-Spirost-5-en-3*β*-yl *O*-*α*-L-rhamnopyranosyl-(1→2) -*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	39
65	(24*S*,25*R*)-24-Hydroxyspirost-5-en-3*β*-yl *O*-*α*-L-rhamnopy-ranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	39
66	(25*S*)-spirost-5-en-3*β*-yl *O*-*β*-D-glucopyranosyl-(1→4)-*O*-*α*-L-rhamnopyranosyl-(1→3)-*β*-D-glucopyranoside	*T. chantriers*	39
67	(24*S*,25*R*)-24-Hydroxyspirost-5-en-3*β*-yl *O*-*α*-L-rhamnopy-ranosyl -(1→2)-O-[*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	39
68	(25*S*)-Spirost-5-en-3*β*-yl-*α*-L-rhamnopyranosyl-(1→2)- *O*-[*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	39
69	Chantrieroside A	*T. chantriers*, *T. integrifolia*	27,40
70	Collettiside IV = (3*β*,25*R*)-Spirost-5-en-3-yl 6-deoxy-*α*-L-mannopy ranosyl-(1→2)-[6-deoxy-*α*-L-rmannopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. cheancer*, *T. chantriers*, *T. integrifolia*, *T. subflabellata*	27,28, 40-43
71	Taccasuboside B	*T. subflabellata*	28
72	Taccasuboside C	*T. subflabellata*	28
73	Taccaoside C	*T. plantaainea*	44
74	Polyphyllin C	*T. chantriers*	27
75	Lieguonin A	*T. plantaainea*	45
76	Lieguonin B	*T. plantaainea*	45

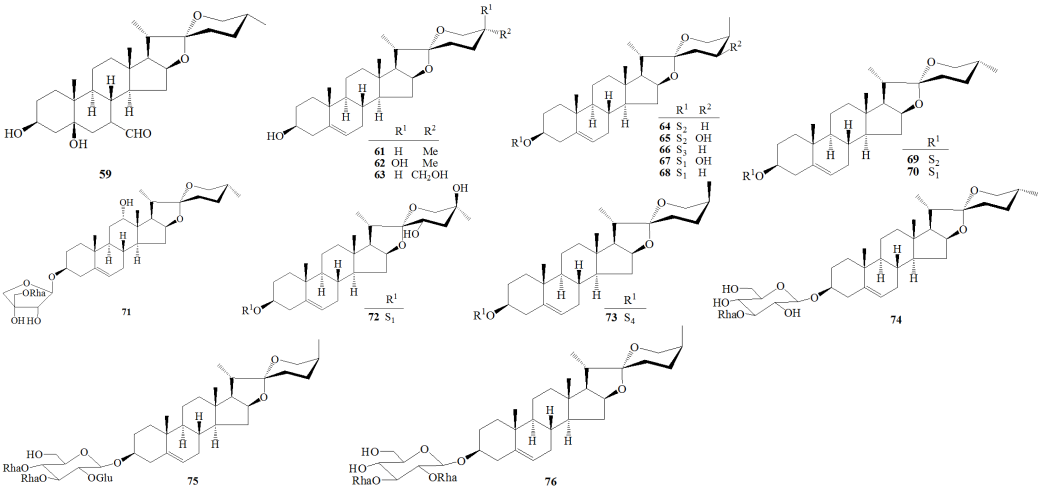

Fig 4: Structures of spirostanol saponins from the *Tacca spps*

withanolide has been found in nature, which is consistent with the biosynthetic hypothesis.

Cholestan saponins

Up to February 2013, eleven C_{28}-sterol oligoglucosides 48-58 (Table 3, Figure 3) were reported from *T. chantriers* [33-35].

Spirostanol Saponins, 59-76 (Table 4, Fig 4)

In 1990, five spirostanols, 59-63, were isolated from *T. leontopetaloides* [36-38]. The rhizomes of *T. chantriers* have been analysed for steroidal saponin constituents, resulting in the isolation of four new spirostanol saponins (64-67), along with one known saponin (68) [39]. Chantrieroside A (69) and collettiside IV (70) were isolated from the same plants of *T. integrifolia* and *T. chantriers* [27,28,40-43]. By analyzing the steroidal content of fresh whole plant of *T. subflabellata*, taccasubosides B-C (71-72) were isolated [28].

Furostanol saponins

Taccaoside A (77), B (78) and D (79), together with twelve furostanol saponins (80-91) (Table 5, Figure 5), were obtained from *T. plantaginea, T. chantriers, T. subflabellata, T. Integrifolia* [28,31,33, 40-41,44,46-48].

Table 5: Furostanol saponins from the genus *Tacca*

No.	Compound name	Species	Ref
77	Taccaoside A	*T. plantaainea*	46
78	Taccaoside B	*T. plantaainea*	46
79	Taccaoside D	*T. plantaainea*	44
80	26-*O*-*β*-D-Glucopyranosyl-(25*S*)-3*β*,22*§*,26-triol-furost-5-ene 3-*O*-*α*-L-rhamnopyranosyl-(1→2)-[*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers, T. subflabellata, T. plantaainea*	28,31, 44,47
81	(25*S*)-26-[(*β*-D-Glucopyranosyl)oxy]furosta-5,20(22)-dien-3*β*-yl *O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*α*-L-rhamnopyranosyl -(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	47
82	(25*S*)-26-[(*β*-D-Glucopyranosyl)oxy]-22*α*-methoxyfurost-5-en-3*β*-yl *O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl -(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	48
83	(25*S*)-26-[(*β*-D-Glucopyranosyl)oxy]-22*α*-methoxyfurost-5-en-3β-yl *O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-6-*O*-acetyl-*β*-D-glucopyranoside	*T. chantriers*	48
84	(25*S*)-26-[(*O*-*β*-D-Glucopyranosyl-(1→6)-*β*-D-glucopyranosyl)oxy]-22*α*-methoxyfurost-5-en-3β-yl *O*-*α*-L-rhamnopyranosyl -(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	48
85	(25*S*)-26-[(*β*-D-Glucopyranosyl)oxy]furosta-5,20(22)-dien-3*β*-yl *O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranos yl -(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	48
86	(25*S*)-26-[(*β*-D-Glucopyranosyl)oxy]-22*α*-methoxyfurosta-5,20(22)-dien-3*β*-yl *O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl -(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-6-*O*-acetyl -*β*-D-glucopyranoside	*T. chantriers*	48
87	(3*β*,22*R*,25*R*)-26-(*β*-D-Glucopyranosyloxy)-22-hydroxyfurost-5-en-3-yl 6-deoxy-*α*-L-mannopyranosyl-(1→2)-[6-deoxy-*α*-L-mannopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. integrifolia*	40,41
88	(3*β*,22*R*,25*R*)-26-(*β*-D-Glucopyranosyloxy)-22-methoxyfurost-5-en-3-yl 6-deoxy-*α*-L-mannopyranosyl-(1→2)-[6-deoxy-*α*-L-mannopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. integrifolia*	40,41
89	(3*β*,22*R*,25*R*)-26-(*β*-D-Glucopyranosyloxy)-22-hydroxyfurost-5-en-3-yl 6-deoxy-*α*-L-mannopyranosyl-(1→2)-[*β*-D-glucopyranosyl -(1→4)-6-deoxy-*α*-L-mannopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. integrifolia*	40
90	(3*S*,22*Z*,25*§*)-26-[(*β*-D-Glucopyranosyl)oxy]-20-hydroxyfurosta-5,22-dien-3*β*-yl *O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl -(1→3)] -[*α*-L-rhamnopyranosyl-(1→2)]-*β*-D-glucopyranoside	*T. chantriers*	33
91	(20*S*,22*Z*,25*§*)-26-[(*β*-D-Glucopyranosyl)oxy]-20-hydroxyfurosta-5,22-dien-3*β*-yl *O*-*α*-L-rhamnopyranosyl (1→2)-*O*-[*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranoside	*T. chantriers*	33

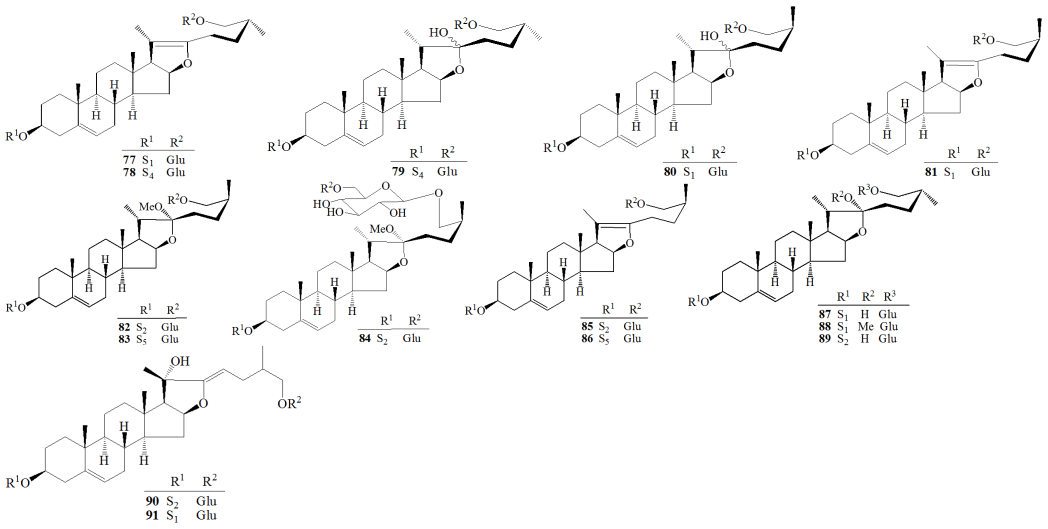

Fig 5: Structures of furostanol saponins from *Tacca spps*

Pregnane glycosides

Five pregnane glycosides, 92-96 (Table 6, Figure 6), were isolated from *T. chantriers* and *T. subflabellata* [28,31,40,47,48]. Compounds 92, 93, 95 are different from 85, 86 in the lack of the signals assignable to the tetrasubstituted olefinic group forming the bond between C (20) and C (22) and in the presence of a ketone carbonyl carbon signal at δ 205.5 and an ester carbonyl carbon signal at δ 173.3. Other steroidals, namely taccagenin (97), nuatigenin (98), stigmasterol (99) and daucosterin (100) (Table 6, Fig 6), were isolated from *T. leontopetaloides* and *T. chantriers* [37-38,43,45].

Diarylheptanoids and their glycosides

One known compound (101), two new diarylheptanoids (102, 103) and ten new diarylheptanoid glucosides (104-113) (Table 7, Fig 7) were isolated from the rhizomes of *T. chantriers* and *T. plantaginea* [49-51].

Table 6: Pregnane glycosides and other steroidals from the genus *Tacca*

No.	Compound name	Species	Ref
92	16*β*-[[(4*S*)-5-(*β*-D-Glucopyranosyloxy)-4-methyl-1-oxopentyl]oxy]-3*β*-[(*O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranosyl)oxy]pregn-5-en-20-one	*T. chantriers*, *T. plantaginea*	31,47
93	16*β*-[[(4*S*)-5-(*β*-D-Glucopyranosyloxy)-4-methyl-1-oxopentyl]oxy]-3*β*-[(*O*-*α*-L-rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranosyl)oxy]pregn-5-en-20-one	*T. chantriers*	48
94	3β-[(*O*-*α*-L-Rhamnopyranosyl-(1→2)-*O*-[*O*-*β*-D-glucopyranosyl-(1→4)-*α*-L-rhamnopyranosyl-(1→3)]-*β*-D-glucopyranosyl)oxy]pregna-5,16-dien-20-one	*T. chantriers*	48
95	(3*β*,16*β*)-3-{[6-Deoxy-α-L-mannopyranosyl-(1→2)-[6-deoxy-*α*-L-mannopyranosyl-(1→3)]-*β*-D-glucopyranosyl]oxy}-20-oxopregn-5-en-16-yl(4*R*)-5-(*β*-D-glucopyranosyloxy)-4-methylpentanoate	*T. integrifolia*	40
96	Taccasuboside D	*T. subflabellata*	28
97	Taccagenin	*T. leontopetaloides*	37
98	Nuatigenin	*T. leontopetaloides*	38
99	Stigmasterol	*T. chantriers*	43
100	Daucosterin	*T. chantriers*, *T. plantaginea*	43,45

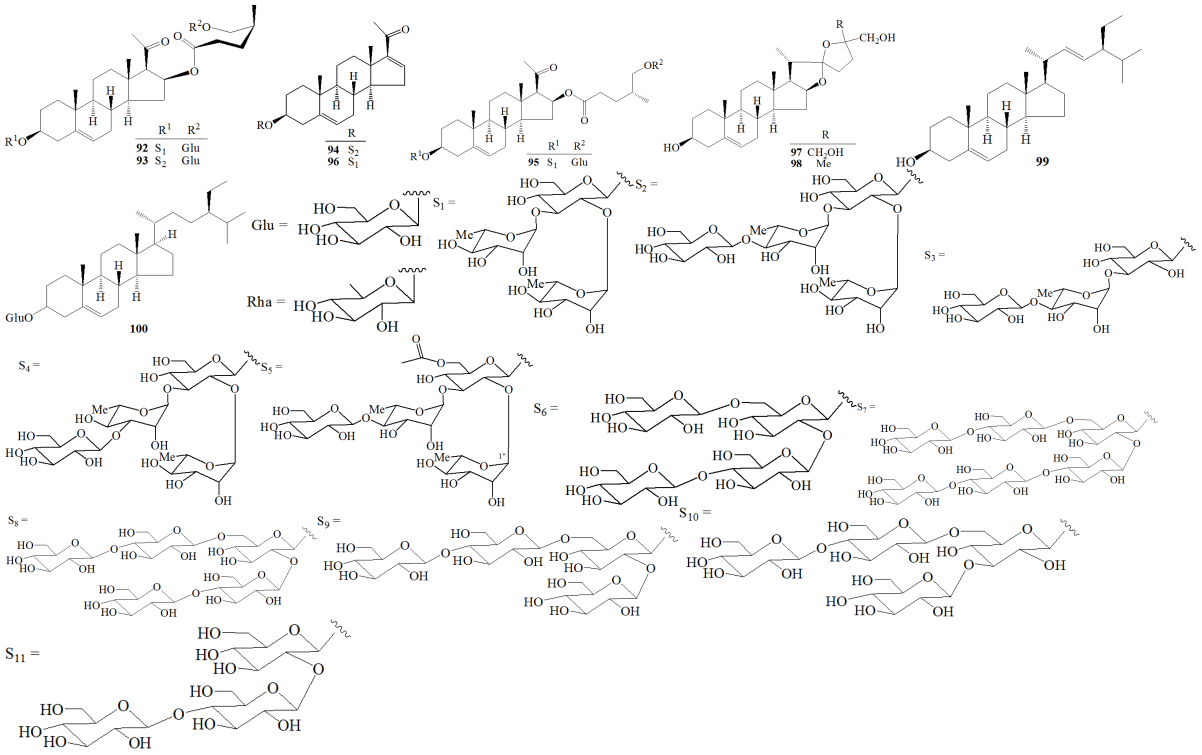

Fig 6: Structures of pregnane glycosides and other steroidal compounds from *Tacca spp*

Table 7: Diarylheptanoids and their glycosides from *Tacca spp*

No.	Compound name	Species	Ref
101	1,7-Bis(4-bis(4-hydroxy-phenyl)-3,5-heptanediol	*T. chantriers*	49
102	(3*R*,5*R*)-3,5-Dihydroxy-1-(3,4-dihydroxyphenyl)-7-(4-hydroxyphenyl)-heptane	*T. chantriers*	50
103	(3*R*,5*R*)-3,5-Dihydroxy-1,7-bis-(3,4-dihydroxyphenyl)heptane	*T. chantriers*	50
104	(3*R*,5*R*)-3,5-Dihydroxy-1-(3,4-dihydroxyphenyl)-7-(4-hydroxyphenyl)-heptane 3-*O*-*β*-D-glucopyranoside	*T. chantriers*	50,51
105	(3*R*,5*R*)-3,5-Dihydroxy-1-(4-hydroxy-3-methoxyphenyl)-7-(4-hydroxyphenyl)heptane3-*O*-*β*-D-glucopyranoside	*T. chantriers*	50
106	(3*R*,5*R*)-3,5-Dihydroxy-1,7-bis(3,4-dihydroxyphenyl) heptane 3-*O*-*β*-D-glucopyranoside	*T. chantriers*	50,51
107	(3*R*,5*R*)-3,5-Dihydroxy-1-(4-hydroxy-3-methoxyphenyl)-7-(3,4-dihydroxyphenyl)heptane 3-*O*-*β*-D-glucopyranoside	*T. chantriers*	50
108	(3*R*,5*R*)-3,5-Dihydroxy-1,7-bis(4-hydroxy-3-methoxyphenyl)-heptane 3-*O*-*β*-D-glucopyranoside	*T. chantriers*	50
109	(3*R*,5*R*)-3,5-Dihydroxy-1,7-bis(4-hydroxyphenyl)heptane 3-*O*-*β*-Dglucopyranoside	*T. chantriers*	50,51
110	(3*R*,5*R*)-3,5-Dihydroxy-1-(3,4-dihydroxyphenyl)-7-(4-hydroxyphenyl) heptane 5-*O*-*β*-D-glucopyranoside	*T. chantriers*	50
111	Plantagineosides A	*T. plantaainea*	51
112	Plantagineosides B	*T. plantaainea*	51
113	Plantagineosides C	*T. plantaainea*	51

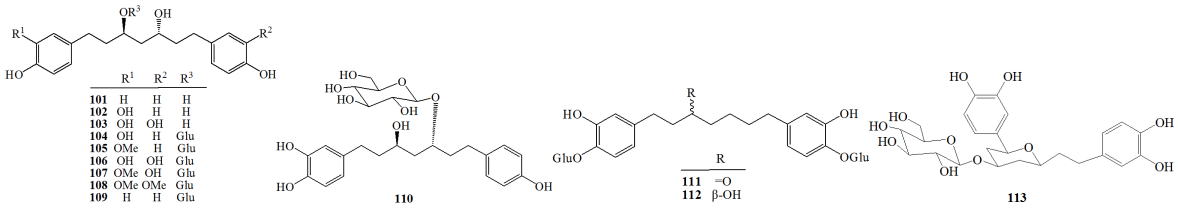

Fig 7: Structures of diarylheptanoids and their glucosides from *Tacca spps*

Table 8: Other compounds from the genus *Tacca*

No.	Compound name	Species	Ref
114	4-[6-*O*-(4-Hydroxy-3,5-dimethoxybenzoyl)-*β*-D-glucopyranosyloxy]-3-methoxybenzoic acid	*T. chantriers*	33
115	Evelynin	*T. chantriers*	52
116	Roseoside	*T. plantaainea*	31
117	Gusanlungionoside D	*T. plantaainea*	31
118	Quercetin-3-*α*-arabinoside	*T. aspera*	53
119	Medicagenic acid	*T. aspera*	53
120	Betulinic acid	*T. aspera*	53
121	α-Monopalmitin	*T. chantriers*	49
122	n-Triacontanol	*T. aspera*	53

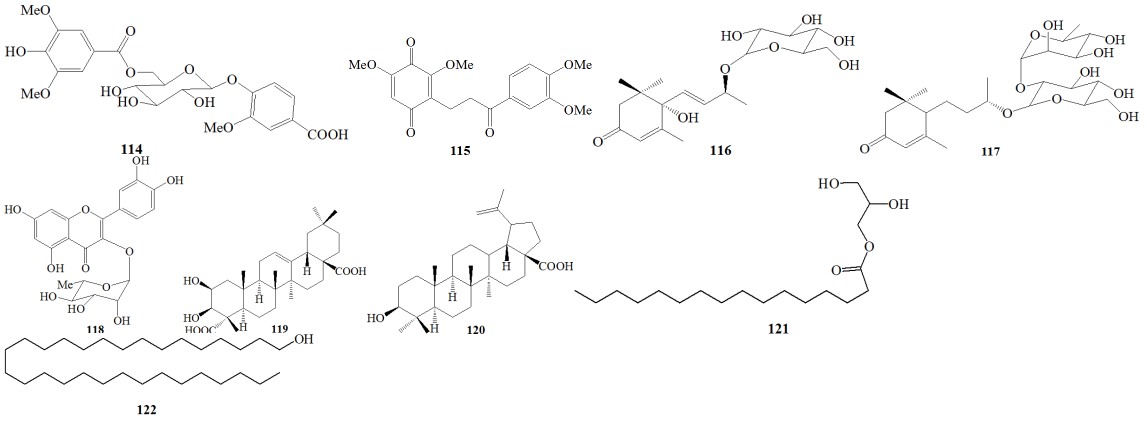

Fig 8: Structures of other compounds from *Tacca spps*

Others compounds

A new phenolic glycoside, 114, and a new benzoquinone-type retro-dihydrochalcone, 115, were isolated from *T. chantriers*, respectively [32,52]. From the MeOH extract of the whole plants of *T. plantaginea*, two megastigmane glycosides are named roseoside (116) and gusanlungionoside D (117) [31]. Quercetin-3-α-arabinoside (118), two triterpenes, namely castanogenin (119) and betulinic acid (120), together with α-monopalmitin (121) and n-triacontanol (122) (Table 8, Fig 8), were isolated from *T. aspera* and *T. chantriers* [48, 53].

Starch

Starch is a natural biodegradable biopolymer which is in high demand recently for use in many industrial products. Search for more new sources of starch from plants, however, has also greatly increased. Tacca starch from *T. leontopetaloides* is found to have higher amylose content than maize starch but a lower content than potato starch. Its features in the formation of compacts (tablets) were comparable to those of maize starch with tacca starch being more resistant to deformation [54]. Maneka *et al* found lower gelatinization temperature and the narrow gelatinization range demonstrated an energy efficient cooking process. It has an implication for the food industry. The weak associative forces stabilizing tacca starch granules could be explored for its potential use as a disintegrant in the pharmaceutical sector [55]. The physico-chemical properties of tacca starch showed potential usefulness of the starch in aqueous and hydrophobic food and drug systems [56].

The plant of *T. involucrata* is a wild plant that contains starch which is eaten when the flour is being cooked with almost 0% fat, usually by the villagers or rural dwellers in the Northern Nigeria as their food. The morphology of the granules was the same for both starches but they differed in granule size distribution: white tacca (6.13-18.12 µm), yellow tacca (4.19-11.98 µm), which were isolated from white and yellow *T. involucrata* tubers [57]. The gelatin at 52-65^{o}C has an amylase content of 36% [58]. It exhibits high water binding capacity, solubility and limited swelling power behavior which are dependent on temperature [59]. The properties are good data sources useful in processing, storage and handling for *Tacca* tubers [60]. Adebiyi *et al* reported that physicochemical properties of starch citrate derivative from *T. involucrata* might be a better disintegrant than native tacca starch in tablet formulations [61]. It shows better swelling and water absorption properties over the

native starch, indicating that *T. involucrata* is a potential source of industrial starch and a promising pharmaceutical excipient [62].

In summary, the type of starch from a non-conventional source *T. leontopetaloides* and *T. involucrata* could reduce the cost of producing starch and eliminate or minimize competition on stable food crops like cassava or potatoes or as a kind of pharmaceutical source.

DISCUSSION

Cytotoxic activity

In the years of 1988 and 1995, Chen *et al* found that taccalonolide A (1) displayed a cytotoxic activity against P-388 leukemia in cell culture [15,49], but taccalonolides G- K (7- 11) showed only a weak cytotoxicity against P 388 leukemia cells *in vitro* [17].

Compounds 64 and 68 showed considerable cytotoxicity with respective IC_{50} values of 1.8 and 2.1 µM, whereas etoposide used as positive control gives an IC_{50} of 0.37 µM against HL-60 leukemia cells. Compounds 65 and 67, the corresponding C (24) hydroxy derivatives of 64, 66, and 68, which are structurally related to 64 with a terminal rhamnosyl group linked to C (2) of the inner glucosyl residue absent from 64, did not show any cell growth inhibitory activity at the sample concentration of 10 µg/ml, suggesting that the structures of both the aglycone and sugar moieties contribute to the cytotoxicity [39]. The cytotoxic activity of compound 70 was evaluated in HeLa cells and shows the highest cytotoxicity value with an IC_{50} of 1.2 ± 0.4 µM. Compounds 69 and 87- 89 exhibited similar cytotoxic properties between 1.5 ± 0.3 to 4.0 ± 0.6 µM [40].

Some compounds were evaluated for their cytotoxic activities against five human cancer cell lines (HL-60, SMMC-7721, A549, MCF-7, and SW480), in which cisplatin (DDP) was used as the reference substance and exhibited IC_{50} values for the cell lines of 1.50 to 25.57 µM, respectively. Taccasubosides A-D (35, 96, 71 and 72, respectively) were inactive (IC_{50} > 40 µM). Compound 70 exhibited a moderate activity against the above cell lines with IC_{50} values from 15.73 to 25.08 µM, while compound 80 with IC_{50} values of 4.63, 4.34, 3.00, 11.13, and 2.68 µM, respectively [28].

Two diarylheptanoids (102, 103) and four glycosides (104, 106, 107, 110), each of which has three or four phenolic hydroxyl groups, showed a moderate cytotoxic activity against HL-60 cells with IC_{50} values ranging from 1.8 to 6.4 µg/mL. Those possessing two phenolic hydroxyl groups (105, 108, 109) didn't exhibit an apparent cytotoxic activity even at a sample concentration of 10 µg/mL. It is noteworthy that compounds whose phenolic hydroxyl groups are all masked with methyl groups are also cytotoxic. These observations suggest that the number of phenolic hydroxyl groups contributes to the resultant cytotoxicity. As for the activity against HSC-2 cells, diarylheptanoids with methyl groups show considerable cytotoxicity. They show much higher cytotoxic activities against HSC-2 cells than against the normal HGF [50]. Evelynin (115) exhibited cytotoxicity against MDA-MB-435 melanoma, MDA-MB-231 breast, PC-3 prostate, and HeLa cervical carcinoma cells, with IC_{50} values being 4.1, 3.9, 4.7, and 6.3 µM, respectively [52].

Microtubule-stabilizing activity

Microtubules remain an important target for anticancer drug discovery. Paclitaxel, a plant-derived microtubule stabilizer, is one of the most successful anticancer drugs currently used. Taccalonolides (oxygenated steroids) are a new class of structurally and mechanistically distinct microtubule-stabilizing agents isolated from plants of the genus *Tacca*. Taccalonolides stand alone among new microtubule stabilizers in that they appear to have a unique mechanism of action which does not involve direct binding to tubulin [63]. Risinger *et al* summarized the biological activities *in vitro* and *in vivo* and their potential advantages over clinically used microtubule stabilizers. They also discussed the challenges in formulation and supply that are to be solved before taccalonolides could become candidates for clinical development [10]. Herein we will review the microtubule stabilizers of taccalonolides for the latest three years.

Peng *et al* found that taccalonolides R (18), T (20), Z(26), AA (27), and AB (28) from *T. chantriers* and *T. integrifolia*, as well as taccalonolides A (1), B (2), E (5) and N (14), displayed microtubule stabilizing activities, but profound differences in antiproliferative potencies were also noted (IC_{50} 32 nM to 13 µM) [21]. These studies demonstrate that diverse taccalonolides possess microtubule stabilizing properties and that significant structure-activity relationships exist. In efforts to define their structure-activity relationships, six taccalonolides AC- H2 (29 - 34), demonstrated cellular microtubule-stabilizing activities and antiproliferative actions against cancer cells, with taccalonolide AJ (33) (an epoxidation product of

taccalonolide B generated by semisynthesis) exhibiting the highest potency with an IC_{50} value of 4.2 nM. The range of potencies of these compounds, from 4.2 nM to > 50 μM, for the first time provided an opportunity to identify specific structural moieties crucial for potent biological activities as well as those that impede optimal cellular effects. In mechanistic assays, taccalonolides AF (32) and AJ (33) could interact directly with tubulin/microtubules and were able to enhance tubulin polymerization to the same extent as paclitaxel but exhibited a distinct kinetic profile, suggesting a distinct binding mode or the possibility of a new binding site [12].

In an effort to find new microtubule stabilizing agents, Risinger *et al* identified taccalonolide AF (32) with an epoxide group bridging C (22)-C (23), the only difference between AF and the major plant component taccalonolide A, and found it shows microtubule stabilizing activity with IC_{50} value of 23 nM in Hela cells. A wide range of antiproliferative potencies was obtained with the natural taccalonolides with IC_{50} values ranging from 23 nM to > 50μM in HeLa cells. A one-step epoxidation reaction was used to synthesize AF (32) from A (1) and AJ (33) from B (2) and AJ is highly potent with an IC_{50} value of 4.2 nM. They found the C (22)-C (23) epoxy group facilitates optimal potency for microtubule stabilizers [64,65].

Clonogenic assays showed that taccalonolide A and radiation act in an additive manner to cause cell death. These studies suggested that diverse antimitotic agents, including the taccalonolides, may have utility in chemoradiotherapy [66]. Risinger *et al* found the close linkage between the microtubule bundling and antiproliferative effects of taccalonolide A were of interest given the recent hypothesis that the effects of microtubule targeting agents on interphase microtubules might play a prominent role in their clinical anticancer efficacy [67]. The latter finding that the anticancer effects of microtubule targeting agents may be due in large part to their interphase effects. The kinetic profile of tubulin polymerization observed in the presence of potent taccalonolides was unlike that observed with other stabilizers, further suggesting that the taccalonolides interact with tubulin in a manner that was markedly distinct from other classes of microtubule targeting agents. The unique biochemical and cell biological properties of these potent taccalonolides, together with the excellent *in vivo* antitumor activity observed for this class of agents in drug resistant tumor models, reveal the potential of taccalonolides as a new class of anticancer drugs [68].

NF-κB activation and PPAR transcriptional activity

Compounds 42, 104, 106, 109 and 113 significantly inhibited TNF α-induced NF-κB transcriptional activity in HepG2 cells with IC_{50} values ranging from 0.9 to 9.4 μM. Chantriolide A-B (42, 43), plantagiolide I-J (45, 46), 80, 92, 104, 106, 109, 111-113, and 116, 117 significantly activated the transcriptional activity of PPARs with EC_{50} values ranging from 0.30 to 49.7 μM. In addition, the transactivational effect of these compounds on three individual PPAR subtypes, including PPARα, β(δ), and γ were evaluated. All of them significantly activated the transcriptional activity of PPARβ (δ), with EC_{50} values in a ranging from 4.1 to 30.1 μM [31,51].These results provide a scientific support for the use of *T. plantaginea* and its components for the prevention and treatment of inflammatory and metabolic diseases.

Insecticidal effect

In 1988, Chen *et al* found that compound 1 has a killing effect on *Plasmodium berghai* [15]. Taccalonolides O-Q (15-17) had no any biological activity, however, neither in the nematicidal screening against *Meloidogyne incognita* nor in the insecticidal screening against *Phaedon cochleariae, Tetranychus urticae*, or *Plutella maculipennis* [25].

CONCLUSION

Phytochemical studies on the plants of this genus have led to the isolation of ca. 122 compounds including steroidals, diaryl-heptanoids, and terpenoids. Some chemical constituents displayed cytotoxic activity, microtubule-stabilizing activity and so on. However, there still arise questions concerning the structure-activity relationships and elucidation of the action mechanism. *Tacca* are important plants not only in the medicinal sense but also as a food source or as an energy material. Thus much more attention should be paid to *Tacca* species for further phytochemical, pharmacological and cultural studies.

ACKNOWLEDGEMENT

We thank Professor X.W. Sun for their help in improving grammatical expressions in the manuscript. The work was supported by a grant

(no. 31260085) from the Natural Science Foundation of China and a grant (no. 2012Y175) for scientific research from the Educational Department of Yunnan, China.

REFERENCES

1. Zhang L, Li HT, Gao LM, Yang JB, Li DZ, Cannon CH, Chen J, Li QJ. Phylogeny and evolution of bracts and bracteoles in Tacca. J Integr Plant Biol 2011; 53: 901-911.
2. Zhang L, Li QJ. Tacca ampliplacenta (Taccaceae), a new species from Yunnan, China. Ann Bot Fennici 2008; 45: 311-314.
3. Keardrit K, Rujjanawate C, Amornlerdpison D. Analgesic, antipyretic and anti-inflammatory effects of Tacca chantriers Andre. J Med Plants Res 2010; 4: 1991-1995.
4. Tiamjan R, Panthong A, Taesotikul T, Rujjanawate C, Taylor WC, Kanjanapothi D. Hypotensive activity of Tacca chantriers and its hypotensive principles. Pharm Biol 2007; 45: 481-485.
5. Mohd-Fuat AR, Kofi EA, Allan GG. Mutagenic and cytotoxic properties of three herbal plants from Southeast Asia. Trop Biomed 2007; 24: 49-59.
6. Kitjaroennirut N, Jansakul C, Sawangchote P. Cardiovascular effects of Tacca integrifolia Ker-Gawl. extract in rats. J Sci Technol 2005; 27: 281- 289.
7. Scheuer PJ, Madamba LA, Swanholm CE. The constituents of Tacca leontopetaloides. Lloydia 1963; 26: 133-140.
8. Risinger AL, Jackson EM, Polin LA, Helms GL, LeBoeuf DA, Joe PA, Hopper-Borge E, Luduena RF, Kruh GD, Mooberry SL. The taccalonolides: microtubule stabilizers that circumvent clinically relevant taxane resistance mechanisms. Cancer Res 2008; 68: 8881-8888.
9. Chen LX, He H, Qiu F. Natural withanolides: an overview. Nat Prod Rep 2011; 28:705-740.
10. Risinger AL, Mooberry SL. Taccalonolides: novel microtubule stabilizers with clinical potential. Cancer Lett 2010; 291: 14-19.
11. Yue QX, Liu X, Guo DA. Microtubule-binding natural products for cancer therapy. Planta Med 2010; 76: 1037-1043.
12. Li J, Risinger AL, Peng J, Chen Z, Hu L, Mooberry SL. Potent taccalonolides, AF and AJ, inform significant structure activity relationships and tubulin as the binding site of these microtubule stabilizers. J Am Chem Soc 2011;133: 19064-19067.
13. Chen ZL, Wang BD, Chen MQ. Steroidal bitter principles from Tacca plantaginea structures of taccalonolide A and B. Tetrahedron lett 1987; 28: 1673-1676.
14. Chen Z L, Shen JH, Gao YS. Some chemical reactions of taccalonolides A - a bitter substance from Tacca plantaginea. Heterocycles 1989; 29: 2103-2108.
15. Chen ZL, Wang BD, Chen MQ. Study on the bitter principles from Tacca plants: structures of taccalonolides A and B. Acta Chim Sin 1988; 46: 1201-1206.
16. Chen ZL, Wang BD, Shen JH. Taccalonolide C and D, two pentacyclic steroids of Tacca plantaginea. Phytochemistry 1988; 27: 2999-3001.
17. Chen ZL, Shen JH, Gao YS, Wichtl M. Five taccalonolides from Tacca plantaginea. Planta Med 1997; 63: 40-43.
18. Yang JY, Zhao RH, Chen CX, Ni W, Teng F, Hao XJ, Liu HY. Taccalonolides W-Y, three new pentacyclic steroids from Tacca plantaginea. Helv Chim Acta 2008; 91: 1077-1082.
19. Shen JH, Chen ZL, Gao YS. The pentacyclic steroidal constituents of Tacca plantaginea: taccalonolide E and F. Chinese J Chem 1991; 9: 92-94.
20. Tinley TL, Randall-HIubek DA, Leal RM, Jackson EM, Cessac JW, Quada JC, Hemscheidt TK, Mooberry SL. Taccalonolides E and A plant-derived steroids with microtubule-stabilizing activity. Cancer Res 2003; 63: 3211-3220.
21. Peng J, Risinger AL, Fest GA, Jackson EM, Helms G, Polin LA, Mooberry SL. Identification and biological activities of new taccalonolide microtubule stabilizers. J Med Chem 2011; 54: 6117-6124.
22. Mühlbauer A, Seip S, Nowak A, Tran VS. Five novel taccalonolides from the roots of the Vietnamese plant Tacca paxiana. Helv Chim Acta 2003; 86: 2065-2072.
23. Mi JF, Chen ZL, Shen JH. Study of circular dichroism of taccalonolide compounds. Acta Pharm Sin 1994; 29:111-115.
24. Shen JH, Chen ZL, Gao YS. Taccalonolides from tacca plantaginea. Phytochemistry 1996; 42: 891-893.
25. Huang Y, Liu JK, Mühlbauer A, Henkel T. Three novel taccalonolides from the tropical plant Tacca subflabellata. Helv Chim Acta 2002; 85: 2533-2558.
26. Huang Y, Mühlbauer A, Henkel T, Liu JK. Two new taccalonolides from tropic plant Tacca subflabellata. Chin Chem Lett 2003; 14: 68-71.
27. Zhang L, Liu JY, Xu LZ, Yang SL. Chantriolide C, a new withanolide glucoside and a new spirostanol saponin from the rhizomes of Tacca chantriers. Chem Pharm Bull 2009; 57: 1126-1128.
28. Li L, Ni W, Li XR, Hua Y, Fang PL, Kong LM, Pan LL, Li Y, Chen CX, Liu HY. Taccasubosides A-D, four new steroidal glycosides from Tacca subflabellata. Steroids 2011; 76: 1037-1042.
29. Liu HY, Ni W, Xie BB, Zhou LY, Hao XJ, Wang X, Chen CX. Five new withanolides from Tacca plantaginea. Chem Pharm Bull 2006; 54: 992-995.
30. Yang JY, Chen CX, Zhao RH, Hao XJ, Liu HY. Plantagiolide F, a minor withanolide from Tacca plantaginea. Nat Prod Res 2011;25: 40-44.
31. Quang TH, Ngan NT, Minh CV, Kiem PV, Yen PH, Tai BH, Nhiem NX, Thao NP, Anh HIe T, Luyen BT, et al. Plantagiolides I and J, two new withanolide glucosides from Tacca plantaginea with nuclear factor-kappaB inhibitory and peroxisome proliferator-

activated receptor transactivational activities. Chem Pharm Bull 2012; 60: 1494-1501.
32. Yokosuka A, Mimaki Y, Sashida Y. Chantriolides A and B, two new withanolide glucosides from the rhizomes of Tacca chantriers. J Nat Prod 2003; 66: 876-878.
33. Yokosuka A, Mimaki Y. New glycosides from the rhizomes of Tacca chantriers. Chem Pharm Bull 2007; 55: 273-279.
34. Yokosuka A, Mimaki Y, Sashida Y. Taccasterosides A-C, novel C-28-sterol oligoglucosides from the rhizomes of Tacca chantriers. Chem Pharm Bull 2004; 52: 1396-1398.
35. Yokosuka A, Mimaki Y, Sakuma C, Sashida Y. New glycosides of the campesterol derivative from the rhizomes of Tacca chantriers. Steroids 2005; 70: 257-265.
36. Abdel-Aziz A, Brain K, Shatalebi MA, Blunden G, Patel A, Crabb TA, Bashir A. A B-ring contracted spirostane from Tacca leontopetaloides. Phytochemistry 1990; 29: 2623-2627.
37. Abdel-Aziz A, Brain K, Blunden G, Crabb T, Bashir A. Isomeric F-ring dihydroxylated 22,25-epoxyfurostene and spirostene sapogenins from Tacca leontopetaloides. Phytochemistry 1990; 29: 1643-1646.
38. Abdel-Aziz A, Brain K, Blunden G, Crabb T, Bashir A. Steroidal sapogenins from Tacca leontopetaloides. Planta Med 1990; 56: 218-221.
39. Yokosuka A, Mimaki Y, Sashida Y. Spirostanol saponins from the rhizomes of Tacca chantriers and their cytotoxic activity. Phytochemistry 2002; 61: 73-78.
40. Shwe HH, Aye M, Sein MM, Htay KT, Kreitmeier P, Gertsch J, Reiser O, Heilmann J. Cytotoxic steroidal saponins from the rhizomes of Tacca integrifolia. Chem Biodivers 2010; 7: 610-622.
41. Heilmann J, Shwe HH, Aye M, Sein MM, Kreitmeier P, Reiser O. New furostanol glycosides from the rhizomes of Tacca integrifolia. Planta Med 2006; 72: P343.
42. Ngok FK, Kelginbaev AN, Gorvits MB, Abubakirov NK. A new steroid glycoside, taccaoside, from Tacca cheancer. Chem Nat Comp 1973; 9: 262-264.
43. Zhou J, Chen CX, Liu RM, Yang CR. Studies on the chemical components of the Tacca chanteraeri Andre. Acta Botanica Sin 1983; 25: 568-573.
44. Liu HY, Ni W, Hao XJ, Chen CX. Steroidal saponins from Tacca plantaginea. J Asian Nat Prod Res 2006; 8: 293-298.
45. Qiu FL, Zhou J, Pu QL. Two new steroidal saponins from Tacca plantaginea Root. Acta Bota Yunnan 1985; 7: 225-231.
46. Liu HY, Chen CX. Two new steroidal saponins from Tacca plantaginea. Chin Chem Lett 2002; 13: 633-636.
47. Yokosuka A, Mimaki Y, Sashida Y. Two new steroidal glycosides from Tacca chantriers. Natural Med 2002; 56: 208-211.
48. Yokosuka A, Mimaki Y, Sashida Y. Steroidal and pregnane glycosides from the rhizomes of Tacca chantriers. J Nat Prod 2002; 65: 1293-1298.
49. Wen DX, Chen ZL. Studies on the chemical constituents of Tacca cheantrieri Andre. in Hainan. Guihaia 1995; 15: 371-373.
50. Yokosuka A, Mimaki Y, Sakagami H, Sashida Y. New diarylheptanoids and diarylheptanoid glucosides from the rhizomes of Tacca chantriers and their cytotoxic activity. J Nat Prod 2002; 65: 283-289.
51. Quang TH, Ngan NT, Minh C, Kiem P, Yen PH, Tai BH, Nhiem NX, Thao NP, Anh HL, Luyen BT, et al. Diarylheptanoid glycosides from Tacca plantaginea and their effects on NF-kB activation and PPAR transcriptional activity. Bioorg Med Chem Lett 2012; 22: 6681-6687.
52. Peng JG, Jackson EM, Babinski DJ, Risinger AL, Helms G, Frantz DE, Mooberry SL. Evelynin, a cytotoxic benzoquinone-type retro-dihydrochalcone from Tacca chantriers. J Nat Prod 2012; 73: 1590-1592.
53. Tripathi RO, Tiwari KP. Phytochemical investigation of the roots of Tacca aspera. Planta Med 1981; 41:414-415.
54. Kunle OO, Ibrahim YE, Emeje MO, Shaba S, Kunle Y. Extraction, physicochemical and compaction properties of tacca starch - a potential pharmaceutical excipient. Starch 2003; 55:319-325.
55. Maneka RV, Kunleb OO, Emejeb MO, Buildersb P, Rao GVR, Lopezc GP, Kollinga WM. Physical, thermal and sorption profile of starch obtained from Tacca leontopetaloides. Starch 2005; 57:55-61.
56. Ukpabi UJ, Ukenye E, Olojede AO. Raw-material potentials of Nigerian wild polynesian arrowroot (Tacca leontopetaloides) tubers and starch. J Food Technol 2009; 7:135-138.
57. Nwokocha LM, Senan C, Williams PA. Structural, physicochemical and rheological characterization of Tacca involucrata starch. Carbohyd Polym 2011; 86:789-796.
58. Attama AA, Adikwu MU. The physicochemical properties of starch derived from Tacca involucrata. Nig J Nat Prod Med 1999; 3:71-73.
59. Zaku SG, Aguzue OC, Thomas SA, Barminas JT. Studies on the functional properties and the nutritive values of amura plant starch (Tacca involucrata) a wild tropical plant. Afr J Food Sci 2009; 3:320-322.
60. Raji AO, Ahemen SA. Engineering properties of Tacca involucrata tubers. J Food Process Eng 2011; 34:267-280.
61. Adebiyi AB, Omojola MO, Orishadipe AT, Afolayan MO, Olalekan D. Tacca starch citrate - a potential pharmaceutical excipient. Arch App Sci Res 2011; 3:114-121.
62. Ahemen SA, Raji AO. Development and performance evaluation of a motorized rasping machine for Tacca involucrate. J Agric Eng Technol 2008; 16:53-64.
63. Buey RM, Barasoain I, Jackson E, Meyer A, Giannakakou P, Paterson I, Mooberry S, Andreu JM,

Diaz JF. Microtubule interactions with chemically diverse stabilizing agents: thermodynamics of binding to the paclitaxel site predicts cytotoxicity. Chem Biol 2005; 12:1269-1279.

64. *Peng J, Li J, Risinger AL, Mooberry SL. Epoxidation at C22-C23 significantly increases the potency of microtubule stabilizing taccalonolides. Planta Med 2012; 78:PI423.*
65. *Li J, Peng J, Risinger AL, Mooberry SL. Structure-activity relationships study of new microtubule stabilizing taccalonolides. Planta Med 2012; 78:PI391*
66. *Risinger AL, Natarajan M, Jr CR, Mooberry SL. The taccalonolides, novel microtubule stabilizers, and c-radiation have additive effects on cellular viability. Cancer Lett 2011; 307,104-111.*
67. *Risinger AL, Mooberry SL. Cellular studies reveal mechanistic differences between taccalonolide A and paclitaxel. Cell Cycle 2011; 10: 2162-2171.*
68. *Risinger AL, Li J, Peng J, Mooberry SL. Potent new microtubule stabilizers with unique biochemical and cellular effects show promise for cancer treatment. Planta Med 2012; 78: PI405.*