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Review

A Review on *Tradescantia*: Phytochemical Constituents, Biological Activities and Health-Promoting Effects

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Abstract

Tradescantia is a genus of herbaceous and perennial plants belonging to the Commelinaceae family and organized into three infrageneric classifications and 12 sections. More than 80 species within the genus have been used for centuries for medicinal purposes. Phytochemical compounds (from various species of the genus) such as coumarins, alkaloids, saponins, flavonoids, phenolics, tannins, steroids and terpenoids have recently been characterized and described with antioxidant, cytotoxic, anti-inflammatory, anticancer or antimicrobial properties. The objective of this review is to describe the different aspects of the genus *Tradescantia,* including its botanical characteristics, traditional uses, phytochemical composition, biological activities, and safety aspects.

Keywords: *Tradescantia*; phytochemicals; bioactive properties; health effects; safety

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1. Introduction

The genus *Tradescantia*, commonly known as 'Spiderwort', is the second largest genus within the Commelinaceae family [1] including approximately 80 herbaceous species classified into 12 sections [2–10]. These species are indigenous to the Neotropics, and the centre of diversity is located in the southern United States and Mexico [3,5,8,9,11] (Table 1, Ref. [2–4,9–15]). These species are adapted to full sun, deep shade, high or low temperatures, and xeric habitats [16].

Tradescantia species are evergreen, perennial or annual, rupicolous or epiphytic, and can reach up to 30–60 cm in height. Roots are thin or thick, and fibrous or tuberous. Stems are aerial, rarely subterranean, prostrate with an ascending or erect apex, forming intertwined dense mats. Leaves are simple, 3–45 cm long, sessile to subsessile, distichously or spirally alternate, glabrous, lanceolate to linear-lanceolate to ovate, evenly distributed along the stem or crowded at the apex. The inflorescence is a terminal crescent, pedunculated, sub-umbelled, with cincinni bracts as leaves or reduced (bracteous), spataceous. Flowers are bisexual, actinomorphic or slightly zygomorphic, pedicellate, pedicel glabrous and green. Sepals are green, equal or subequal, polysepalous or connate below and persistent. Petals can be white, pink, or purple, but mostly bright blue, equal or subequal, and free or connate below the floral tube. Stamens are equal or subequal, epipetalous; filaments free, usually bearded at the base, glabrous or with moniliform hyaline trichomes at the base, anthers oblong or reniform, basifixed or dorsifixed. Carpels are pubescent, ovary 3-locular, style straight, cylindrical to subcylindrical, glabrous. The fruit is a 3-cell loculicidal capsule. Seeds 1–2 per locule, reniform to ellipsoid usually rugose [2,12,13].

T. zebrina Bosse, *T. fluminensis* Vell., *T. spathacea* Swartz. and *T. albiflora* Kunth. are the most widely studied species within the *Tradescantia* genus. Ethnopharmacological uses of *Tradescantia* include anti-inflammatory, antioxidant, antibacterial and antiarrhythmic applications. All parts of the plant are potentially useful and, although the phytochemical characterization has been described for some species, most *Tradescantia* species remain unreported. No species have been tested for drug development aside from toxicity studies. Thus, the objective of this review is to describe all known aspects of the genus *Tradescantia* including its botanical characteristics, traditional uses, phytochemical composition, biological activities, and safety aspects.

A literature search was performed in PubMed/MEDLINE using the terms '*Tradescantia*' and 'global distribution', 'traditional uses', 'phytochemical', 'antioxidant', 'inflammatory', 'biological properties' or 'human health', individually or in combination. Scientific articles from the last five years including the phytochemical characterization and evaluation of biological properties of *Tradescantia* species through *in vitro* and *in vivo* models, were prioritized for inclusion in this review.

2. Traditional Uses

Herbs have traditionally beed used for their fragrance, taste, and therapeutic properties. Fresh or dried herbs have been applied in tablet or capsule form as contemporary methods (powders, teas and extracts) [17]. Some species of the genus *Tradescantia* have been traditionally used for their presumed anti-inflammatory, antioxidant, antibacterial and antiarrhythmic properties. For example, roots have been used as a drink to heal kidney diseases and digestive system ailments. Leaves have been applied to relieve stings and insect bites. A summary of worldwide traditional uses of the genus *Tradescantia* is shown in Table 2 (Ref. [18–27]). Traditional remedies must be interpreted and considered with great caution as possible potentialities of this plant source. Therefore, scientific evidence is needed to demonstrate the cause-and-effect relationship of these properties.

T. zebrina (Fig. 1) has widely been used as traditional Chinese medicine for renal system diseases. In Jamaica, high blood pressure, cough and tuberculosis have been treated with this plant. Specifically, the leaves are considered to have beneficial properties to reduce inflammation and treat haemorrhoids and kidney infections. In Mexico, a decoction of the leaves are traditionally consumed as a cold drink called 'Matali' [25]. In the Caribbean, leaf extracts are consumed to relieve kidney and urinary problems, and reduce intestinal inflammation [23]. In the past, Filipinos used the leaves as tea to cleanse the blood and relieve influenza symptoms [24]. Malaysians recommended a decoction of the plant to improve kidney function and was believed to have advantages for treating venomous snake bite, leucorrhoea, urinary tract infection, nephritis and bowel inflammation. *T. pallida* D.R.Hunt has also been traditionally used for its anti-inflammatory and antitoxic potential, as well as improving blood circulation and prevent sore eyes [26]. *T. spathacea,* also known as *Rhoeo spathacea* or *Rhoeo disccolor*, has been used in China in a decoction of dried or fresh leaves and flowers to treat dysentery and haemoptysis [20]. In Singapore, traditional medicinal uses of this plant focus on treating fever, cough, and bronchitis. In spite of all these properties, its sap is considered to have adverse effects related to itching of the skin and eyes, and abdominal and oral pain when ingested [28].

These traditional uses may suggest the presence of potential bioactive compounds (in their chemical composition) capable of preventing or alleviating certain diseases. The lack of scientific evidence necessary to prove such applications must be carried out through appropriate scientific methods. Recent studies allow these traditional uses to be translated into future applications of modern medicine.

Table 1. Global distribution of *T.* species [2–4,9–15].

Section	Species				Distribution
	Nº	Name			
Cymbispatha	9	*T. comme linoides* Schult. & Schult.f. *T. cymbispatha* C.B.Clarke *T. deficiens* Brandegee	*T. tonalamonticola Matuda* *T. tonalamonticola* Matuda *T. venezuelensis* Steyerm. *T. plusiantha* Standl. *T. standleyi* Steyerm.	*T. gracillima* Standl.	Bolivia From Mexico to Brazil
Coholomia	1		*T. guatemalensis* C.B.Clarke ex J.D.Sm.		Guatemala
Tradescantia.	29	*T. bracteata* Small ex Britton *T. canaliculata* Raf. *T. edwardsiana* Tharp *T. ernestiana* E.S.Anderson & Woodson *T. gigantea* Rose *T. hirsuticaulis* Small *T. hirsutiflora* Bush *T. humilis* Rose *T. virginiana* L. *T. orchidophylla* Rose & Hemsl.	*T. longipes* E.S.Anderson & Woodson *T. occidentalis* (Britton) Smyth *T. ohiensis* Raf. *T. ozarkana* E.S.Anderson & Woodson *T. paludosa* E.S.Anderson & Woodson *T. reverchonii* Bush *T. roseolens* Small *T. subacaulis* Bush *T. subaspera* Ker Gawl. *T. tharpii* E.S.Anderson & Woodson	*T. rozynskii* Matuda *T. sillamontana* Matuda *T. cirrifera* Mart. *T. maysillesii* Matuda *T. monosperma* Brandegee *T. nuevoleonensis* Matuda *T. pinetorum* Greene *T. wrightii* Rose & Bush *T. mirandae* Matuda	USA, Texas Mexico (From Chihuahua to Puebla)
Setcreasea	5	*T. brevifolia* (Torr.) Rose *T. buckleyi* (I.M.Johnst.) D.R.Hunt	*T. hirta* D.R.Hunt *T. leiandra* Torr.	*T. pallida* (Rose) D.R.Hunt	Texas Mexico (From Chihuahua to Veracruz)
Separotheca	1		*T. pygmaea* D.R.Hunt		Mexico (Durango)
Mandonia	7	*T. ambigua* Mart. ex Schult. & Schult.f. *T. burchii* D.R.Hunt *T. crassifolia* Cav.	*T. llamasii* Matuda *T. peninsularis* Brandegee	*T. tepoxtlana* Matuda *T. velutina* Kunth & C.D.Bouché	Mexico (Durango)
Parasetcreasea	1		*T. andrieuxii* C.B.Clarke		Mexico (From Chihuahua to Oaxaca)
AustroT.	6	*T. anagallidea* Seub. *T. umbraculifera* Hand.-Mazz.	*T. cerinthoides* Kunth *T. crassula* Link & Otto	*T. fluminensis* Vell. *T. ambigua* Mart. ex Schult. & Schult.f.	Argentina, southern and southeastern Brazil, Bolivia, Paraguay, Uruguay
Rhoeo	1		*T. spathacea* Sw.		Mexico, Belize
Campelia	1		*T. zanonia* (L.) Sw.		Tropical America
Zebrina	1		*T. zebrina* Bosse		From Mexico to Venezuela
Corinna	1		*T. soconuscana* Matuda		Mexico, Guatemala, Nicaragua, Costa Rica

Table 2. Summary of global traditional uses of the genus *Tradescantia*.

Plant species	Country/Region	Plant part(s)	Traditional usage for treatment of	Instruction	Ref.
T. spathacea	*Southern Mexico*	Whole plant	Coughs and loosen mucus	1 teaspoon of plant extract obtained from grinding mixed with a little sugar (3 times/day)	[18]
	Southern Mexico	Stem and Leaves	Vomiting of blood	1 tablespoon of decoction (3 times/day)	[18,19]
	Southern Mexico	Leaves	Burns, scalds and dysentery	poultice	[18]
	China	Whole plant	Wounds	poultice	[18]
	China	Flower	Dysentery	-	[18]
	China	leaves and flowers	Dysentery, entrorrhagia and hemoptysis	Decoction	[20]
	Singapore	Leaves	fever, cough and bronchitis, decorative	Decoction	[21]
	Puerto Rico	Leaves	Psoriasis	Decoction	[21]
	Cuba	Leaves	Grazes	poultice	[21]
T. zebrina	China	Leaves mixed with other types of herbs	Blood tonic and to treat amenorrhea	-	[22]
	Caribbean	Leaves	To flush gravel out of the kidneys and bladder, break the crisis of colitis	Decoction	[23]
	Philippines	Leaves	Cleansing blood and treating influenza,	Tea	[24]
	Mexico	Leaves	-	Cold iced tea drink	[25]
	Caribbean	Leaves	To flush gravel out of the kidneys and urinary system, improves bowel inflammation	Decoction	[23]
T. pallida	Philippines	Leaves	Sore eyes	-	[26]
T. virginiana L.	America	Roots	Insect stings to reduce pain and itching	Ointment	[27]

Fig. 1. *T. zebrina*. Adapted from https://plants.ces.ncsu.edu/plants/Tradescantia-zebrina/.

3. Phytochemical Composition

The therapeutic value and pharmacological effects of medicinal plants largely depend on their phytochemical composition. In the case of *Tradescantia*, the phytochemical composition has only been explored for a few species. Entire characterization studies are based on phytochemicals qualitative analysis or simple screening of compound families. Phytochemicals quantitative studies in *Tradescantia* species have not yet been carried out.

Alkaloids, flavonoids, phenolics and saponins have been the most identified phytochemical compounds in *Tradescantia* species [29–32]. Apigenin, luteolin and flavonols, 6-hydroxyluteolin and tricin, have been the main identified flavonoids (*C*-glycosides). The geographical origin of *Tradescantia* species has been described as a factor that affects the content of these compounds. Lee Tan *et al*. [33] determined the total phenolic content (TPC), total tannin content (TTC) and total flavonoid content (TFC) of *T. spathacea, T. pallida* and *T. zebrina* methanolic extracts (Table 3, Ref. [33]). Cheah. *et al*. [34] also determined the TPC (33.5 $\pm$ 2.6 mg GAE/g extract) and TFC (9.4 $\pm$ 1.1 mg CE/g extract) of a methanolic extract of *T. zebrina* leaves.

Del Pero Martínez *et al*. [35] were the first to qualitatively analyse the flavonoid composition in 42 *Tradescantia* species. Luteolin, apigenin, 6-hydroxyluteolin and tricin glycosides were the most commonly characterized flavonoids.

Table 3. Total phenolic content (TPC), total tannin content (TTC) and total flavonoid content (TFC) of *T. spathacea*, *T. pallida* and *T. zebrina* [33].

	TPC (mg GAE/100 g sample)	TTC (mg TAE/100 g sample)	TFC (mg RE/100 g sample)
T. spathacea	203.9 ± 16.3	20.6 ± 2.3	10.8 ± 2.9
T. pallida	153.1 ± 21.8	13.6 ± 2.1	10.6 ± 4.0
T. zebrina	620.9 ± 39.7	57.6 ± 3.5	17.1 ± 2.8

GAE, Gallic acid equivalent; RE, Rutin equivalent; TAE, Tannic acid equivalent.

Phytochemical screening analyses of *T. spathacea* leaf extracts showed the presence of coumarins, alkaloids, saponins, flavonoids and terpenoids [31]. In another screening study, alkaloids, steroids, flavonoids, saponins, cardiac glycoside, terpenoids, tannins and phenolic compounds were detected in a *T. spathacea* leaf extract [29]. Flavonoids, alkaloids, tannins, phenols and steroids were characterized from *T. zebrina* leaf extracts. *T. fuminensis* leaf extracts analysis revealed the presence of saponins, phenolic compounds and flavonoids [30,32]. Huq *et al*. [36] carried out a phytochemical screening of *T. pallida* extracts, detecting the presence of alkaloids, tannins and carbohydrates, in high, moderate and trace amounts, respectively. However, no specific metabolites were isolated or identified.

Studies on *T. zebrina, T. spathacea and T. albiflora* have focused on specifically characterising the phytochemical compounds of the species (Table 4). For example, Dash *et al*. [22], identified the compounds ecdysone (1), β-sitosterol (2), 3β,5α,6β-trihydroxy stigmastrol (3) and succinic acid (4) in *T. zebrina* (Fig. 2). Various phenolics and carotenoids compounds identified in *T. spathacea* have been associated to antitumor and/or antioxidant activities [37]. Quoc Hung Vo *et al*. [38] characterized two new phytochemicals in *T. spathacea* by NMR and MS: (±)-tradescantin (5) and tradecantoside. In addition, 14 previously described phytochemical compounds (Nº: 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22; Table 4, Fig. 2) were characterized in this study by spectroscopic data comparison. Lee Tan *et al*. [39], identified four phenolic compounds (epigallocatechin (25), rhoeonoin (26), peltatoside (27) and rutin (28)) in *T. spathacea* leaves by HPLC-DAD-MS. In a study based on HPLC-DAD-TOF-MS, García-Varela *et al*. [40], identified the following metabolites in *T. spathacea*: rhoeonin (26), ferulic acid (29), vanillic acid (30), glycosylated vanillic acid (31) *p*-coumaric acid (32), and chlorogenic acid (33).

Shi *et al*. [41] found that *T. pallida* contained two main anthocyanins with natural food colorant potential. One was cyanidin 3,7,3′-triglucoside with three ferulic acid and extra terminal glucose molecules, and the remaining compound had similar chemical structure though lacking the glucose terminal unit.

Wang *et al*. [42] discovered that particular compounds isolated from *T. albiflora* extracts were able to reduce serum uric acid levels in oxonate-induced rats. The methanol extract of *T. albiflora* was fractionated successively using different polarities solvents such as hexane, ethyl acetate and *n*-butanol. Repeated column chromatography of the ethyl acetate extract resulted in the purification of the following twelve aromatic compounds: hydroxytyrosol (6), protocatechuic acid (7), 2-hydroxy-3′,4′-dihydroxyacetophenone (9), 3,4-dihydroxymethylbenzoate (10), 3-(3′,4′-dihydroxyphenyl)-butenolide (11), bracteanolide A (21), bracteanolide B (23), tyrosol (34), indole-3-aldehyde (35), 2-phenylacetamide (36), *p*-hydroxybenzaldehyde (37) and *p*-hydroxybenzoic acid (38) (Fig. 2). These phytochemicals were characterized by MS and NMR. In a recent study, three new secondary metabolites were characterized in *T. albiflora* by MS, 1D-NMR and 2D-NMR. These metabolites were two butanolides (5-*O*-acetyl bracteanolide A (24) and rosmarinosin B (39)), and an apocarotenoid (2β-hydroxyisololiolide (40)) [43]. In addition, 25 previously known metabolites were also identified in this study (Nº: 5, 22, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57 and 58; Table 4, Fig. 2).

Although crucial, these findings are not sufficient for a general understanding of the phytochemical compounds found in most *Tradescantia* species. These studies are based on qualitative characterizations, and therefore the concentration levels of these phytochemical compounds in *Tradescantia* species are currently unknown.

In spite of the large number of existing *Tradescantia* species, there is still a lack of knowledge regarding their qualitative and quantitative phytochemical composition. Considering the advantages of high-resolution analytical techniques, quantitative and qualitative phytochemical studies are necessary to clarify the cause-effect relationship of the beneficial properties.

4. Biological Activities

The different bioactive properties described for *Tradescantia* species might be related to their phytochemical composition. For instance, several studies have reported the bioactive properties of epigallocatechin, such as antioxidant, antidiabetic, anti-inflammatory or antitumor activities [44]. Hydroxytyrosol is also a phytochemical compound to which antioxidant, anti-inflammatory, anticancer, antidiabetic or cardioprotective properties, have

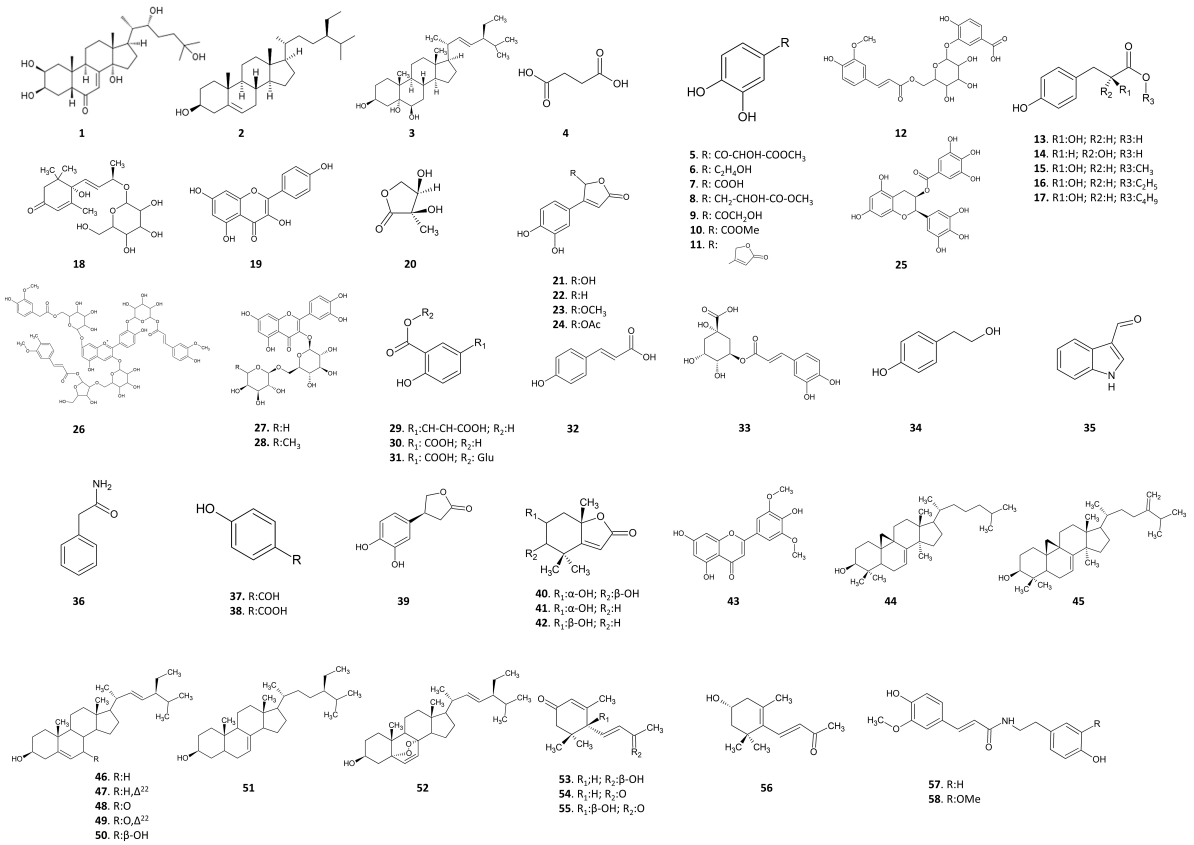

Fig. 2. Phytochemical compounds characterized in different *T.* species (*T. zebrina*, *T. albiflora*, *T. pallida*): 1. ecdysone; 2. β-sitosterol; 3. 3β, 5α, 6β-trihydroxy stigmastrol; 4. succinic acid; 5. tradescantin; 6. hydroxytyrosol; 7. protocatechuic acid; 8. oresbiusin A; 9. 2-hydroxy-3′,4′-dihydroxyacetophenone; 10. 3,4-dihydroxymethylbenzoate; 11. 3-(3′,4′-dihydroxyphenyl)-butenolide; 12. tradecantoside; 13. (*S*)-2-hydroxy-3-(4′-hydroxyphenyl) propanoic acid; 14. (*R*)-2-hydroxy-3-(4′-hydroxyphenyl) propanoic acid; 15. latifolicinin C; 16. latifolicinin B; 17. latifolicinin A; 18. (6*S*,9*R*)-roseoside; 20. (2*R*,3*R*)-2,3-dihydroxy-2-methylbutyrolactone; 21. bracteanolide A; 22. 4-(3′,4′-dihydroxyphenyl)furan-2(5*H*)-one; 23. bracteanolide B; 24. 5-*O*-acetyl bracteanolide A; 25. epigallocatechin; 26. rhoenoin; 27. peltatoside; 28. rutin; 29. ferulic acid; 30. vanillic acid; 31. glycosylated vanillic acid; 32. *p*-coumaric acid; 33. chlorogenic acid; 34. tyrosol; 35. indole-3-aldehyde; 36. 2-phenylacetamide; 37. *p*-hydroxybenzaldehyde; 38. *p*-hydroxybenzoic acid; 39. rosmarinosin B; 40. 2β-hydroxyisololiolide; 41. isololiolide; 42. loliolide; 43. tricin; 44. 3-epicyclomusalenol; 45. 24,25-dihydrocimicifugenol; 46. sitosterol; 47. stigmasterol; 47. 7-ketositosterol; 49. 7-ketostigmasterol; 50. 7-hydroxysitosterol; 51. schottenol; 52. ergosterol peroxide; 53. (6*R*,7*E*,9*R*)-9-hydroxy-4,7-megastigmadien-3-one; 54. (*E*)-3,5,5-trimethyl-4-(3-oxobut-1-en-1-yl)cyclohex-2-enone; 55. (*S*)-dehydrovomifoliol; 56. (3*R*)-3-hydroxy-β-ionone; 57. *N-trans*-feruloyltyramine; 58. *N-trans*-feruloyl-3-methoxytyramine.

been described [38]. Much of the bioactive properties of specific compounds present in *Tradescantia* plants have recently been reviewed by Tan *et al.* [45], highlighting the following compounds: rutin, epigallocatechin, (6*S*,9*R*)-roseoside, kaempferol, oresbiusin A, hydroxytyrosol, protocatechuic acid, latifolicin (A, B and C) and ferulic, vanillic, chlorogenic, and *p*-coumaric acids. Kaempferol, protocatechuic acid, rutin, epigallocatechin, have been described in other plant sources as antioxidant and anticancer compounds [46]. Although individual compounds may have proven individual bioactive properties, it is also important to consider the bioactive potential of *Tradescantia* extracts in case of possible synergistic effects between compounds. However, only few studies have been conducted to evaluate the bioactivity of *Tradescantia* extracts (Table 5, Ref. [30,32–34,37,39,43,47–54]). The following subsections describe the main studies carried out on the evaluation of the bioactive properties of *Tradescantia* extracts.

4.1 Antioxidant Activity

The antioxidant capacity of vegetable or food sources has become increasingly important as a strategy to combat oxidative stress. Oxidative stress is a biological process produced by an imbalance between the production of reactive oxygen species (ROS) in tissues and cells, and the ability of a biological system to repair the resulting damage by antioxidant agents. This imbalance can cause toxic effects through the production of peroxides and free radicals

Table 4. Phytochemical compounds detected in *Tradescantia* species (*T. Zebrina, T. spathace and T. albiflora*).

Nº	Name	*T. Zebrina*	*T. spathacea*	*T. albiflora*	Nº	Name	*T. spathacea*	*T. albiflora*
1	Ecdysone	X			30	vanillic acid	X	
2	β-sitosterol	X			31	glycosylated vanillic acid	X	
3	3β,5α,6β-trihydroxy stigmastrol	X			32	*p*-coumaric acid	X	
4	Succinic acid	X			33	chlorogenic acid	X	
5	(±)-tradescantin		X	X	34	tyrosol		X
6	hydroxytyrosol		X	X	35	indole-3-aldehyde		X
7	protocatechuic acid		X	X	36	2-phenylacetamide		X
8	oresbiusin A		X		37	*p*-hydroxybenzaldehyde		X
9	2-hydroxy-3′,4′-dihydroxyacetophenone		X	X	38	*p*-hydroxybenzoic acid		X
10	3,4-dihydroxymethylbenzoate			X	39	rosmarinosin B		X
11	3-(3′,4′-dihydroxyphenyl)-butenolide			X	40	2β-hydroxyisololiolide		X
12	tradecantoside		X		41	isololiolide		X
13	(*S*)-2-hydroxy-3-(4′-hydroxyphenyl) propanoic acid		X		42	loliolide		X
14	(*R*)-2-hydroxy-3-(4′-hydroxyphenyl) propanoic acid		X		43	tricin		X
15	latifolicinin C		X		44	3-epicyclomusalenol		X
16	latifolicinin B		X		45	24,25-dihydrocimicifugenol		X
17	latifolicinin A		X		46	sitosterol		X
18	(6*S*,9*R*)-roseoside		X		47	stigmasterol		X
19	kaempferol		X		48	7-ketositosterol		X
20	(2*R*,3*R*)-2,3-dihydroxy-2-methylbutyrolactone		X		49	7-ketostigmasterol		X
21	bracteanolide A		X	X	50	7β-hydroxysitosterol		X
22	4-(3′,4′-dihydroxyphenyl)furan-2(5*H*)-one		X	X	51	schottenol		X
23	bracteanolide B			X	52	ergosterol peroxide		X
24	5-*O*-acetyl bracteanolide A			X	53	(6*R*,7*E*,9*R*)-9-hydroxy-4,7-megastigmadien-3-one		X
25	epigallocatechin		X		54	(*E*)-3,5,5-trimethyl-4-(3-oxobut-1-en-1-yl)cyclohex-2-enone		X
26	rhoeonin	X	X		55	(*S*)-dehydrovomifoliol		X
27	peltatoside		X		56	(3*R*)-3-hydroxy-β-ionone		X
28	rutin		X		57	*N-trans*-feruloyltyramine		X
29	ferulic acid		X		58	*N-trans*-feruloyl-3-methoxytyramine		X

Table 5. Main studies focused on evaluating the bioactive activities of the extracts of *Tradescantia* species.

Activity	Specie	Extract (Dose)	Model	Results	REF
Antioxidant activity	*T. zebrina, T. pallida*	Methanolic leaf extract	FRS, FRP, FIC	*T. zebrina* showed the highest antioxidant activity	[33]
	T. spathacea	Aqueous and methanol leaf extracts	FRS, FRP, FIC	Decoction and infusion extracts showed an antioxidant activity similar to herbal teas	[39]
	T. zebrina	Methanolic leaf extracts (0.1 mg/mL)	DPPH	A radical scavenging activity of 18.1 ± 1.6%	[34]
Anti-inflammatory activity	*T. fluminensis*	Ethanolic leaf extract (Dose: 150, 300 mg/kg)	Egg albumin induced paw edema model. Adult Wistar albino rats	A significant dose-dependent inhibition of inflammation	[32]
	T. albiflora	Isolated compounds from *T. albiflora*	LPS-stimulated NO production in RAW 264.7 cells	Bracteanolide A, methyl 3,4-dihydroxybenzoate and hydroxytyrosol show inhibitory potential	[43]
	T. fluminensis and *T. zebrina*	Methanol leaf extracts (0.2 µg/mL)	15-Lipoxygenase inhibitory assay	Higher than 50% of inhibition. *T. fluminensis* showed higher inhibitory potential (87.2%)	[30]
Anticancer activity	*T. fluminensis* and *T.zebrina*	Methanol and aqueous extracts (2.5, 5%)	A549, SCC-13y and HFF-1 cells	Inhibitory effects on cancerous lines (lung adenocarcinoma, squamous cell carcinoma and human foreskin fibroblasts)	[47]
	T. zebrina	Aqueous and methanol extracts	SCC-13y malignant keratinocyte cells and A-549 lung carcinoma cells	Effects of *T. zebrina* on cancerous cells	[48]
	T. spathacea	Leaf extract	Human breast adenocarcinoma (MCF-7)	IC_{50} = 299.7 µg/mL	[49]
	T.spathacea	Aqueous crude extract (20 mg/kg)	Rat resistant-hepatocyte carcinogenesis model	A reduction of the number and area of preneoplastic lesions.	[37]
	T. pallida	ZnO nanoparticles using *T. pallida* leaf extract (0–1000 µg/mL)	HeLa cervical cancer cell line	Cytotoxicity againt cercival cancer cell line	[50]
Cytotoxic activity	*T. zebrina*	Extracts obtained with different solvents. (5–640 μg/mL)	NRU and MTT assays. Monkey kidney epithelial (Vero) cells.	A concentration dependent and extraction solvent dependent cytotoxic effect	[51]
Insecticidal activity	*T. zebrina*	Infusion extract of dry plant (2.5–10% m/v)	*Anopheles benarrochi* larvae	LC_{50} value of 0.86% after 24 hours of exposure	[52]

Table 5. Continued.

Activity	Specie	Extract (Dose)	Model	Results	REF
Antibacterial/Antimicrobial activities	*T. zebrina, T. pallida* and *T. spathacea*	Leaf extracts (0.02–10 mg/mL)	6 species of Gram-positive (Methicillin-Resistant *Staphylococcus aureus, Proteus vulgaris, Bacillus cereus, Aeromonas hydrophila, Bacillus subtilis, Enterococcus faecalis, Micrococcus luteus, Staphylococcus epidermidis*)	The three species showed antibacterial activity. *T. zebrina* exhibited the best antibacterial potential.	[33]
	T. spathacea	Fresh and dried extracts	*Moniliophthora roreri*	A prevention of the growth of *M. roreri* at concentrations of 40–50%	[53]
Acetylcholinesterase inhibitory activity	*T. zebrina*	methanolic leaf extracts (100.00 and 10.00 µg/mL)	Acetylcholinesterase activity assay using the standard Ellman method with slight modifications	Significant decreases in acetylcholinesterase activity ($p <$ 0.05)	[34]
Modulation of the immune response	*T. spathacea*	Aqueous leaf extract (1 ng/mL–100 μg/mL)	Lymphoproliferation assay and NK cell activity assay	Stimulation of the human lymphocyte proliferative response	[54]

that damage all components of the cell, including proteins, lipids, and DNA. The biological effects of ROS are controlled in aerobic organisms by a range of physiological antioxidant defense mechanisms, which involve a complex group of processes aimed at preventing or retarding excess oxidation at the cellular level and in some cases reversing the oxidative damage of the affected molecules. There are different molecules involved in the antioxidant system which are mainly classified into endogenous or exogenous antioxidants. Endogenous antioxidants include several enzymes (e.g., glutathione peroxidase, catalase, superoxide dismutase, etc.) and non-enzymatic (e.g., glutathione, bilirubin, uric acid, etc.) compounds. Exogenous antioxidants are mainly obtained from the diet, including vitamins (e.g., vitamins A, C, E), carotenoids (e.g., lutein, zeaxanthin, and lycopene), phenolic compounds (e.g., flavonoids, phenolic acids), glucosinolates and organosulfur compounds. Due to the different families of compounds with possible antioxidant properties present in natural sources such as phenolic compounds or carotenoids, many investigations have focused on studying their antioxidant, anticancer and anti-inflammatory potential through *in vitro* cell lines and animal models [55]. The antioxidant activities of phenolic compounds are based on their ability to be excellent donors of hydrogen, which are accepted by reactive radicals to yield much less active radical and non-radical species [56]. There are different methods for evaluating antioxidant capacity such as the oxygen radical absorbance capacity assay (ORAC), Trolox equivalent antioxidant capacity assay (TEAC), ferric reducing antioxidant power assay (FRAP) and 2,2-diphenyl-1-picrylhydrazyl assay (DPPH) [57]. The DPPH and ORAC assays involve a hydrogen atom transfer reaction. The ORAC assay measures the radical chain-breaking ability of antioxidants by monitoring the inhibition of peroxyl radical-induced oxidation. Peroxyl radicals are the predominant free radicals found in lipid oxidation in foods and biological systems. DPPH radical scavenging test is a sensitive antioxidant assay and depends on substrate polarity. The presence of multiple hydroxyl functions could be considered as an option for hydrogen donation and/or radical scavenging activity. Ferroptosis is one of the effects of ROS overproduction, which is a type of iron-dependent oxidative cell death caused by a variety of factors. Ferroptosis is different from apoptosis but is also the result of dysfunction of antioxidant defense, leading to the loss of cellular redox homeostasis. In contrast, TEAC and FRAP assays are based on single-electron transfer. The FRAP method is based on the reduction of Fe (III) to Fe (II) [58]. Antioxidants capable of chelating and reducing iron (III) ions are potential candidates for controlling ferroptosis and their destructive effects on healthy cells [46]. Tan *et al*. [33] studied the antioxidant activity of *T. zebrina*, *T. pallida* and *R. spathacea* by DPPH free radical scavenging (FRS), ferrous ion chelating (FIC), and phenolic ferric reducing power (FRP) assays. Their results revealed that *T. zebrina* showed the highest antioxidant capacity values (FRS: 906.5 $\pm$ 88.2 mg AA equivalent/100 g; FRP: 4.8 $\pm$ 0.3 mg GAE/g). Sinha *et al*. [59], described the antioxidant activities of *T. pallida,* showing this plant can combat oxidative stress.

4.2 Anti-inflammatory Activity

Inflammation is defined as an immune response of a living organism against numerous infectious agents such as viruses or bacteria. Some examples of common signs of inflammation are redness, pain or fever. The use of synthetic drugs against inflammatory processes has shown efficacy, but side effects are also often produced. Due to the phytochemical composition of many plant sources with anti-inflammatory potential, the use of these plants, including several *Tradescantia* species, has been studied as possible alternatives to alleviate inflammatory processes. For example, *T. fluminensis,* commonly known as *Wandering Jew*, has been identified as one of the species with anti-inflammatory potential. Tu *et al*. [43] evaluated the anti-inflammatory potential of compounds isolated from *T. albiflora*, finding that bracteanolide A, methyl 3,4-dihydroxybenzoate and hydroxytyrosol have great inhibitory potential against nitric oxide (NO) production in a RAW 264.7 cell model. NO production occurs during inflammatory processes and is, therefore, a good indicator of the extent of inflammation. Among the three compounds evaluated, 5-*O*-*n*-butyl bracteanolide A showed the highest anti-inflammatory potential.

In another study, the inhibitory activity of lipoxygenase produced by *T. fluminensis* and *T. zebrina* leaf extracts was assessed [30]. Lipoxygenase was involved in the production of lipid mediators, which played an important role in inflammatory processes. *T. fluminensis* showed the highest potential with an inhibition value of 87%.

4.3 Cytotoxic Activity

Chan *et al*. [51] evaluated the cytotoxicity of six medicinal plants, including *T. zebrina,* using neutral red uptake (NRU) and 3-(4,5 dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assays. In this study, six extracts obtained with different solvents (chloroform, ethanol, methanol, water, ethyl acetate and hexane) were evaluated. The cytotoxicity activity was evaluated in a monkey kidney epithelial cell (Vero) model using extract concentrations ranging from 5 to 640 μg/mL. The results showed that the chloroform, hexane and ethyl acetate extracts exhibited a higher level of toxicity to Vero cells than the aqueous, methanolic and ethanolic extracts. Therefore, the results indicated that the evaluated medicinal plants, including *T. zebrina*, showed cytotoxicity depending on the concentration and the extraction solvent. It was also detected that the NRU assay showed a higher level of reliability and sensitivity compared to the MTT assay to evaluate the cell viability of plant extracts.

Li *et al*. [50] synthesized zinc oxide nanoparticles (ZnO NPs) using an aqueous leaf extract (TPALE) of *T. pallida* to evaluate their cytotoxic and fluorescent properties. Specifically, 20 mg of TPALE were mixed with 80 mL of zinc acetate (1 mM) for nanoparticle formation. Subsequently, the solution was centrifuged and the pellet heated at 350 ºC for 5 hours. The synthesized ZnO NPs were characterized using several techniques (e.g., scanning electron microscopy, transmission electron microscopy, X-ray diffraction). The resulting rod-shaped particles had a size of 25 ± 2 nm. The cytotoxic effects of the nanoparticles were evaluated against a HeLa cell line using the MTT assay. The results showed that 98.9% of the cancer cells died when treated with a 1000 mg/mL dose of ZnO NP. This indicated that the biogenic ZnO NP had an enhanced cytotoxic property against the cervical cancer cell line which could potentially be further developed as an anticancer drug. However, this dose is considered high, and therefore more studies should be carried out to verify the reproducibility of these results using a lower dose.

4.4 Anticancer Activity

Brauner *et al*. [47] evaluated the anticancer effects of methanolic and aqueous extracts of *T. flumin*ensis and *T. zebrina* on A549 (lung adenocarcinoma), SCC-13y (squamous cell carcinoma) and HFF-1 (human foreskin fibroblasts) cell models [47]. The results showed a decrease in the cancer cell proliferation rate, especially when *T. zebrina* was added to the treatment. Therefore, this study confirmed the inhibitory capacity of *T. fluminensis* and *T. zebrina* on cancer and non-cancer cells. Moehring *et al*. [48] evaluated the anticancer properties of methanolic and aqueous extracts of *T. zebrina* on SCC-13y and A-549 cell models. The number of cells was counted for five days to assess the rate of inhibition by the plant extract. The results showed a reduction in cell growth in both cell lines. In addition, the extracts were evaluated against a non-cancerous cell line (HFF-1) to assess the relative toxicity of the extracts. *T. zebrina* showed an inhibitory potential against both non-cancer and cancer cells.

Rosales-Reyes *et al.* [37] evaluated the protective effects of a crude *T. spathacea* aqueous extract against liver cancer using the carcinogenesis model of resistant hepatocytes in rats. The aqueous crude extract, with dose below 20 mg/kg of body weight, reduced the number and area of preneoplastic lesions. The administration of the aqueous extract produced no promoter or initiator effects, nor induce the development of altered hepatocytes foci. In another study, Prakash *et al*. [49] evaluated the anticancer potential of *T. spathacea* leaf extract against a human breast adenocarcinoma cell line (MCF-7). The results showed that a 50% inhibition of MCF-7 was detected at a dose of 299.7 μg/mL. Cai-Yun *et al*. [50], found that the synthetic ZnO particles, based on *T. pallida,* showed cytotoxic effects against a cervical cancer cell line.

4.5 Antifungal and Antibacterial Activities

Cocoa has been identified as a large cash crop for the production of chocolates, with social, economic and environmental impacts. Pests and diseases are factors that significantly affect the quality of cocoa beans. *Moniliophthora roreri* has been identified as one of the main pathogenic fungi that affect the quality of cocoa plants. To prevent this phenomenon, España *et al.* [53], evaluated the inhibitory effects of *T. spathacea*, *Origanum vulgare* and *Zingiber officinale* extracts against the growth of *M. roreri*. The results showed that all three plants prevented the growth of *M. roreri* conidia, using concentrations of 40–50% of both fresh and dry plants.

T. zebrina, *T. pallida* and *T. spathacea* leaves methanolic extracts showed antibacterial activity against methicillin-resistant *Staphylococcus aureus*, Proteus vulgaris, *Bacillus cereus*, *Aeromonas hydrophila*, *Bacillus subtilis*, *Enterococcus faecalis*, *Micrococcus luteus*, and *Staphylococcus epidermidis* [33].

4.6 Other Biological Activities

Other biological activities have also been studied for various species of *Tradescantia*. For instance, the larvicidal effect against *Anopheles benarrochi* has been studied using different concentrations of a *T. zebrina* tea extract (2.5–10% m/v). A median lethal concentration (LC_{50}) of 0.86% was obtained after 24 hours of exposure [52].

Chunxin *et al*. [60] evaluated the antiarrhythmic activity of β-ecdysone, isolated from *T. zebrina* by applying aconitine as an arrhythmia inducer in animals. This study showed that the biologically active compounds present in the composition of *Tradescantia* species has potentially significant antiarrhythmic activity.

Cheah *et al*. [34], evaluated the *in vitro* acetylcholinesterase inhibitory activity of *T. zebrina* leaves methanolic extract [34]. This enzyme has been associated with many diseases, especially neurodegenerative disorders such as Alzheimer's disease. The results indicated a significant decrease in acetylcholinesterase activity ($p < 0.05$) of 14.0 and 15.3% when concentrations of 100.00 and 10.00 μg/mL of extract were applied, respectively.

Sriwanthana *et al*. [54] evaluated the effect of *T. spathacea* and seven medicinal plants species, against natural killer (NK) cells, a type of cell of the innate immune system. All cells were found to significantly enhance human lymphocyte proliferative responses when exposed to high concentrations in a dose-dependent manner. The authors found that the studied plant species had stimulating effect on human lymphocytes, playing an important role in modulating the immune response.

Despite the numerous species within this genus *Tradescantia*, very few have been biologically explored, with *T. zebrina*, *T. spathacea*, *T. fluminensis*, and *T. pallida* being the most studied. In general, it is necessary to continue studying the biological activities of *Tradescantia*

species, increasing the number of assays in *in vivo* models to allow a greater advance in knowledge. Further studies should be performed to ensure the results reproducibility detailed in this review. In addition, the bioactivity, bioavailability, and bioaccessibility studies of the phytochemical compounds are also necessary. It is key to understand the compounds capable of reaching the target tissues to exert beneficial properties. There is still a lack of knowledge in relation to the bioactive properties of these extracts or compounds, to be used in modern medicine applications. More studies should therefore be performed on the bioactive properties, bioavailability, metabolism, and long-term effects of *Tradescantia* extracts to increase scientific evidence and translate the traditional uses of these plants into food or modern medicine applications.

5. Safety and Adverse Effects

Plants contain many different biologically active substances, some of which have proven healing properties, while others are harmful to human health and cause adverse effects [61]. The latter are usually low molecular weight endogenous toxins or secondary metabolites produced by plants for protection from animals, insects or microorganisms [62]. Plant toxins are generally classified into the following four main groups based on the chemical structure: alkaloids, glycosides, proteins, and saponin glycosides [61,62]. The presence of phytochemicals in *Tradescantia* extracts, such as alkaloids, flavonoids, tannins, and phenols, indicate potential toxic properties of plant, although, reports on adverse reactions of compounds from this plant are scarce [22,32]. This is due to the fact that the harmful effects of herbaceous plants are pourly controlled in comparison to the pharmaceuticals counterpart [63].

According to Filmer *et al*. [64], *Tradescantia* spp. belong to the fourth class of toxicity, which means that the juice, sap or thorns of this plant can cause skin rash or irritation. This potential toxicity may be attributed to calcium oxalate crystals found in the parenchymal tissues of the stem, leaves, roots, and flowers [65]. Plants in humid environments can cause the plant cells to secrete these crystals, which can then come into contact with the skin [66]. In December 2019, the FDA's Poisonous Plant Database listed 5 titles that mention the toxicity of this plant. Only one case of a 32-year-old patient allergic to *Tradescantia* spp. (*T. albifloxia* and *T. fluminensis*) has been confirmed in humans [67]. The patient exhibited an itchy face, throat, and conjunctiva, swollen lips, and dyspnea [68] in addition to previous atopic dermatitis. In a recent study, Wang *et al*. [69] revealed that a methanolic extract of *T. zebrina* leaves could induce cytochrome (CYP) 3A4, an enzyme activity that metabolizes drugs in human liver microsomes. Some studies have suggested that *T. fluminensis* may show adverse effects in dogs, causing allergic reactions (red and itchy skin) [70]. More *in vivo* studies should be conducted to further confirm the effect of *Tradescantia*. spp. in the human body system.

Despite these few examples of possible negative effects on human health, these plants have been used in beverage production and in folk medicine. However, the lack of specific information on the negative impact of whole plants or extracts obtained from these plants on human health, it can only be determined that their main bioactive compounds have a negative effect on human health.

The 3-epicyclomusalenol, a phytochemical found in *Tradescantia* spp., has also been identified as a phytochemical compound of banana (*Musa sapientum*) [71] and brown algae (*Kjellmaniella crassifolia*) [72]. According to the Human Metabolome Database (HMDB) (http://www.hmdb.ca/), no side effects data has been reported for this compound. Ergosterol peroxide, also obtained from *Ananas comosus* (pineapple) and fungus *Ganoderma lucidum* [73], represents a promising new reagent to overcome drug resistance of tumour cells, though no information on the biological side effects and interactions of this compound have been described. Methyl 3,4-dihydroxybenzoate is an antioxidant polyphenol (found in green tea) that attenuates fluoride toxicity on lung epithelial cells [74]. 4-Hydroxybenzoic acid is a low toxicity, antioxidant capable of stimulating the oestrogenic response in human breast cancer cells [75]. Some phytosterols have been reported to have more or less pronounced cytotoxic effects on normal cells. Despite the fact that β-sitosterol has been recognized as safe, diarrhoea, nausea and indigestion have been described as common side effects after intake. The use of β-sitosterol is not recommended in children, whereas in pregnant women this compound should be avoided because of the proven uterine stimulating effects [76]. It is well known that β-sitosterol should not be used in sitosterolemia, due to the fact that sitosterol and other fats abnormally accumulate in the blood. The most recent results in a mouse model showed that stigmasterol leads to left ventricular dysfunction, cardiac interstitial fibrosis, and macrophage infiltration without atherosclerosis and increased mortality [77]. On the other hand, according to the European Food Safety Authority (EFSA), there is no evidence of mutagenicity or genotoxicity of phytosterols or phytosterol esters and, therefore, stigmasterol-rich plants are not a genotoxicity concern [78].

In conclusion, no relevant toxicological data are available on plants belonging to the genus *Tradescantia*, though long-term history use in humans show no safety concerns for the oral or oromucosal use of the preparations of these plants are apparent. Based on these plant matrices, further toxicological studies are necessary to establish their safety prior to commercialization of products.

6. Conclusions

T. zebrina, *T. fluminensis, T. spathacea,* and *T. albiflora* are the most widely studied species within the genus *Tradescantia*. Although research has mainly focused on the phytochemical composition and/or biological activities of *Tradescantia* species, most of the literature is based

on traditional applications, descriptive analyzes, and non-medicinal uses. *T. zebrina* has been the most commonly studied species within the genus concerning bioactivity.

To develop potential therapeutic applications based on *Tradescantia* compounds, it is necessary to increase the knowledge regarding the biological mechanisms of action of these compounds. More studies should be conducted to better explore the phytochemical composition both quantitatively and qualitatively, as well as the corresponding tests to examine their bioactive activities. The application of modern approaches, such as genomics, proteomics, metabolomics, and transcriptomics, should be considered for future studies of this genus. Given the large number of species in the genus *Tradescantia*, a more systematic approach is necessary to ensure data are consistently collected in future studies.

Abbreviations

AA, Ascorbic acid; DPPH, 2,2-Diphenyl-1-picrylhydrazyl assay; FIC, ferrous ion chelating; FRAP, ferric reducing antioxidant power assay; FRS, Free radical scavenging; FRP, phenolic ferric reducing power; GAE, Gallic acid equivalent; MS, Mass spectrometry; MTT, 3-(4, 5 dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide; NMR, Nuclear magnetic resonance; NRU, neutral red uptake; ORAC, oxygen radical absorbance capacity assay, RE, Rutin equivalent; TAE, Tannic acid equivalent; TEAC, Trolox equivalent antioxidant capacity assay; TFC, total flavonoid content; TPC, total phenolic content; TTC, total tannin content.

Author contributions

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Ethics approval and consent to participate

Not applicale.

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Conflict of interest

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