



Review

UV Filters: Challenges and Prospects

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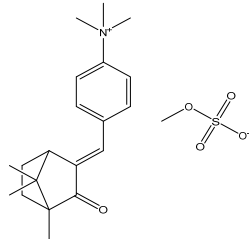
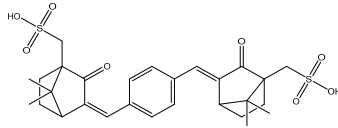
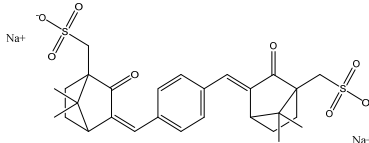
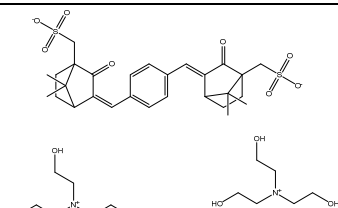
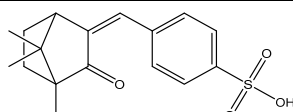
⁶ Center for Neuroscience and Cell Biology, 3004-504 Coimbra, Portugal.

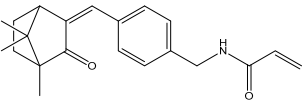
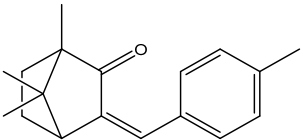
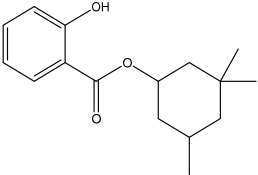
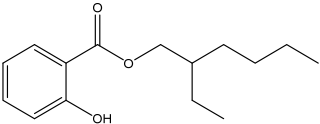
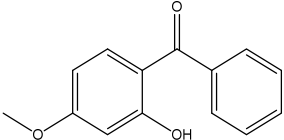
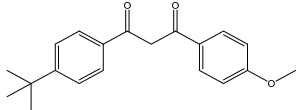
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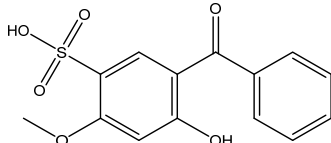
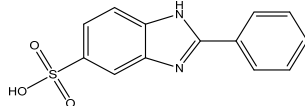
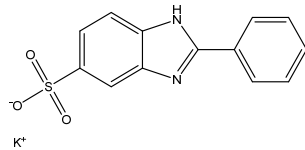
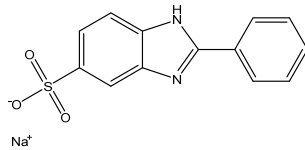
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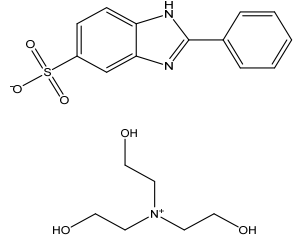
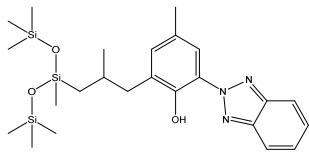
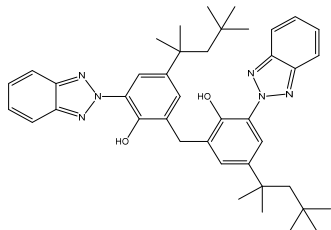
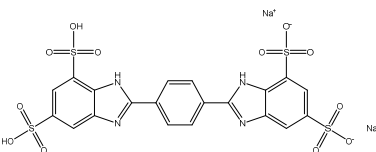
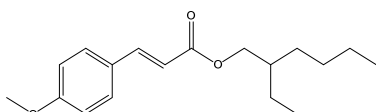
Table S1. List of UV filters approved for use in cosmetics products in EU in 2009 (actualized version in October 2021).

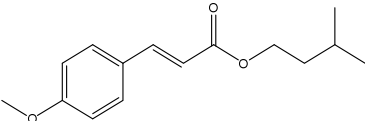
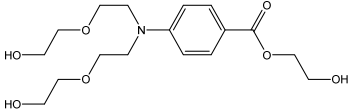
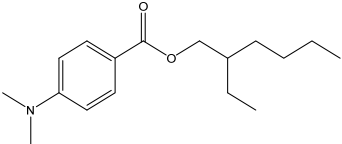
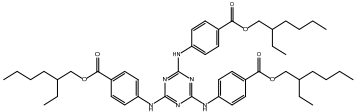
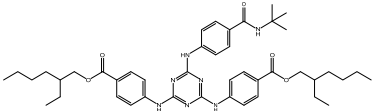
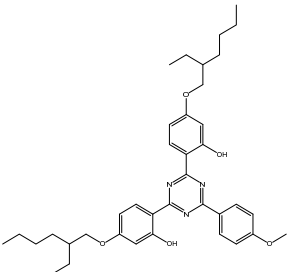
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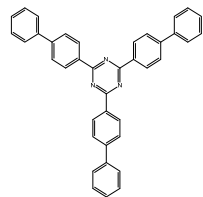
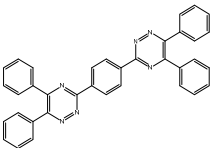
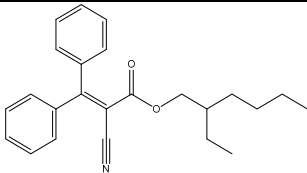
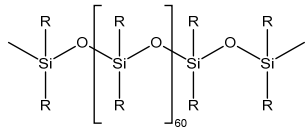
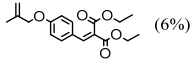
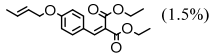
Number	Chemical structure	Chemical name ^a	INCI name and Abbreviation ^b	Maximum concentration allowed ^c	Characteristics ^{a,c}	Molecular weight (g/mol) ^a
Organic UV Filters						
Camphor derivatives						
1		<i>N,N,N</i> -trimethyl-4-[(<i>E</i>)-(4,7,7-trimethyl-3-oxobicyclo[2.2.1]hept-2-ylidene)methyl]anilinium methyl sulfate	Camphor benzalkonium methosulfate (CBM)	6%	Organic UVB absorber	409.54
2		[(3 <i>E</i>)-3-[[4-[(<i>Z</i>)-[7,7-dimethyl-3-oxo-4-(sulfomethyl)-2-bicyclo[2.2.1]heptanylidene]methyl]phenyl]methylidene]-7,7-dimethyl-2-oxo-1-bicyclo[2.2.1]heptanyl]methanesulfonic acid				562.69
3		disodium;[(3 <i>E</i>)-3-[[4-[(<i>Z</i>)-[7,7-dimethyl-3-oxo-4-(sulfonatomethyl)-2-bicyclo[2.2.1]heptanylidene]methyl]phenyl]methylidene]-7,7-dimethyl-2-oxo-1-bicyclo[2.2.1]heptanyl]methanesulfonate	Terephthalate dicamphor sulfonic acid/ Ecamsule (TDSA) and its sodium and amine salts	10%	Organic UVA absorber	606.7
4		2-bis(2-hydroxyethyl)aminoethanol;3-[[4-[[7,7-dimethyl-3-oxo-4-(sulfomethyl)-2-bicyclo[2.2.1]heptanylidene]methyl]phenyl]methylidene]-7,7-dimethyl-2-oxo-1-bicyclo[2.2.1]heptanyl]methanesulfonic acid				861.1
5		4-[(4,7,7-trimethyl-3-oxo-2-bicyclo[2.2.1]heptanylidene)methyl]benzenesulfonic acid	Benzylidene camphor sulfonic acid (BCSA)	6%	Organic UVB absorber	320.40

6		Polymer of <i>N</i> -[(2 and 4)-[(2-oxoborn-3-ylidene)methyl]benzyl]acrylamide 2-Propenamide, <i>N</i> -[[4-[(4,7,7-trimethyl-3-oxobicyclo[2.2.1]hept-2-ylidene)methyl]phenyl]methyl]-, homopolymer	Polyacrylamidomethyl benzylidene camphor (PBC)	6%	Organic UVB absorber	323.44
7		(3 <i>E</i>)-1,7,7-trimethyl-3-[(4-methylphenyl)methylidene]bicyclo[2.2.1]heptan-2-one	4-Methylbenzylidene Camphor/ Enzacamene (4-MBC)	4%	Organic UVB and UVA absorbers	254.37
Salicylate derivatives						
8		(3,3,5-trimethylcyclohexyl) 2-hydroxybenzoate	Homosalate (HMS)	10%	Organic UVB and UVA absorber	262.35
9		2-ethylhexyl 2-hydroxybenzoate	Ethylhexyl salicylate/ octisalate (EHS)	5%	Organic UVB and UVA absorber	250.34
Benzophenone and dibenzoylmethane derivatives						
10		(2-hydroxy-4-methoxyphenyl)(phenyl) methanone/ oxybenzone	Benzophenone-3 (BP-3)	6%	Organic UVB and UVA absorber Benzophenone derivative	228.25
11		1-(4- <i>tert</i> -butylphenyl)-3-(4-methoxyphenyl)propane-1,3-dione	Butyl methoxydibenzoylmethane/ avobenzene (BMDBM)	5%	Organic UVB and UVA absorber	310.4

						Dibenzoylmethane derivative
12		5-benzoyl-4-hydroxy-2-methoxybenzene-1-sulfonic acid	Benzophenone-4/ sulisobenzone (BP-4)	5%	Organic UVB and UVA absorber	308.30
13		sodium;5-benzoyl-4-hydroxy-2-methoxybenzenesulfonate	Benzophenone-5 (BP-5)		Benzophenone derivatives	330.29
Benzimidazole and Benzotriazole derivatives						
14		2-phenyl-1 <i>H</i> -1,3-benzodiazole-5-sulfonic acid				274.29
15		Potassium 2-phenyl-1 <i>H</i> -1,3-benzodiazole-5-sulfonate	Phenylbenzimidazole sulfonic acid/ Ensulizole (PBSA)	8%	Organic UVB and UVA absorber	312.38
16		Sodium 2-phenyl-1 <i>H</i> -1,3-benzodiazole-5-sulfonate			Benzimidazole derivative	296.28

17		Triethanolamine 2-phenyl-1H-1,3-benzodiazole-5-sulfonate				423.48
18		2-(benzotriazol-2-yl)-4-methyl-6-[2-methyl-3-[methyl-bis(trimethylsilyloxy)silyl]propyl]phenol	Drometrizole Trisiloxane (DRT)	15%	Organic UVB and UVA absorbers Benzotriazole derivative	501.85
19		2-(benzotriazol-2-yl)-6-[[3-(benzotriazol-2-yl)-2-hydroxy-5-(2,4,4-trimethylpentan-2-yl)phenyl]methyl]-4-(2,4,4-trimethylpentan-2-yl)phenol	Bisotrizole/ Bisotrizole (nano) (MBBT)	10%	Organic UVB and UVA absorber Benzotriazole derivative	658.89
20		disodium;6-sulfo-2-[4-(6-sulfo-4-sulfonato-1H-benzimidazol-2-yl)phenyl]-1H-benzimidazole-4-sulfonate	Bisdisulizole disodium (DPDT)	10%	Organic UVA absorber Benzimidazole derivative	674.55
Cinnamate derivatives						
21		2-ethylhexyl 4-methoxycinnamate	Ethylhexyl methoxycinnamate/octinoxate (EHMC)	10%	Organic UVB and UVA absorber	290.40

22		3-methylbutyl (E)-3-(4-methoxyphenyl)prop-2-enoate	Isoamyl p-methoxycinnamate/ amiloxate (IMC)	10%	Organic UVB and UVA absorber	248.32
PABA derivatives						
23		2-hydroxyethyl 4-(bis(2-(2-hydroxyethoxy)ethyl)amino)benzoate	PEG-25 PABA	10%	Organic UVB absorber	357.40
24		2-ethylhexyl 4-(dimethylamino)benzoate	Padimate O (EHDB)	8%	Organic UVB absorber	277.41
Triazine and Triazone Derivatives						
25		2-ethylhexyl 4-[[[4,6-bis[4-(2-ethylhexoxycarbonyl)anilino]-1,3,5-triazin-2-yl]amino]benzoate	Octyl triazone/ Ethylhexyl triazone (OT/ EHT)	5%	Organic UVB and UVA absorber Triazone derivative	823.09
26		2-ethylhexyl 4-[(4-[[[4-(tert-butylcarbamoyl)phenyl]amino]-6-[(4-((2-ethylhexyl)oxy)carbonyl]phenyl)amino]-1,3,5-triazin-2-yl]amino]benzoate	Diethylhexyl Butamido Triazone/ Iscotrizinol (DBT)	10%	Organic UVB and UVA absorbers Triazone derivative	765.98
27		5-(2-ethylhexoxy)-2-[4-[4-(2-ethylhexoxy)-2-hydroxyphenyl]-6-(4-methoxyphenyl)-1,3,5-triazin-2-yl]phenol	Bemotrizinol (BEMT)	10%	Organic UVB and UVA absorber Triazine derivative	627.83

28		2,4,6-tris(4-phenylphenyl)-1,3,5-triazine	Tris-biphenyl triazine and Tris-biphenyl triazine (nano) (TBT/TBPT)	10%	Organic UVB and UVA absorber Triazine derivative	537.67
29		3,3'-(1,4-phenylene)bis(5,6-diphenyl-1,2,4-triazine)	Phenylene Bis-Diphenyl triazine	5%	Organic Triazine derivative UVA and UVB absorber Triazine derivatives	540.63
Other classes						
30		2-ethylhexyl 2-cyano-3,3-diphenylprop-2-enoate	Octocrylene (OC/ OCR)	10%	Organic UVB and UVA absorber	361.49
31	 R = H (0.1-0.4%) CH ₃ (92.1-92.5%)  (6%)  (1.5%)	Dimethicodiethylbenzalmalonate	Polysilicone-15 (PS-15)	10%	Organic UVB and UVA absorber	-

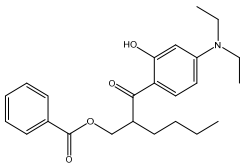
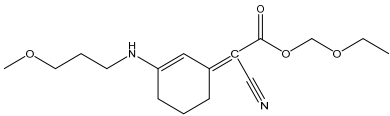
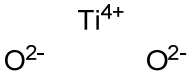
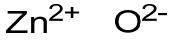
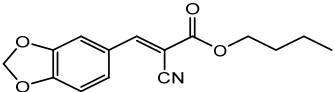
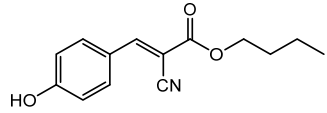
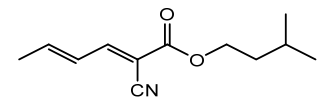
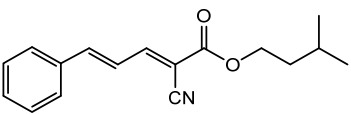
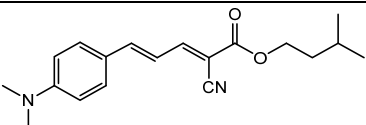
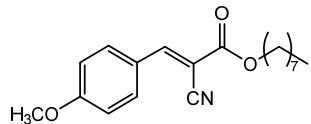
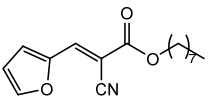
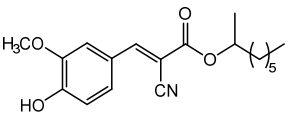
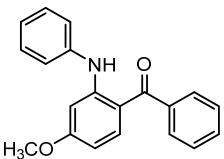
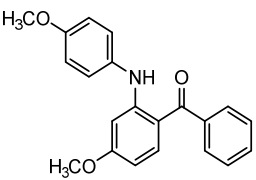
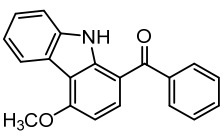
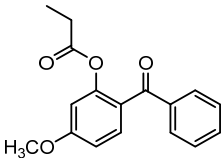
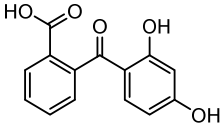
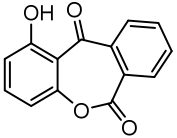
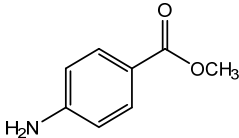
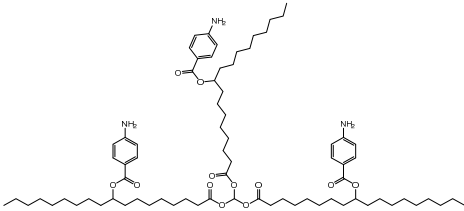
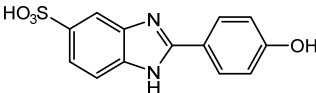
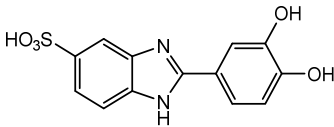
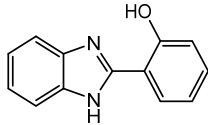
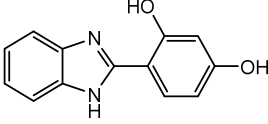
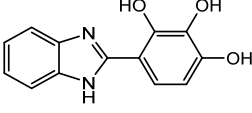
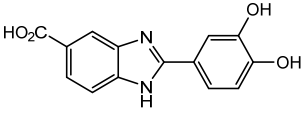
32		hexyl 2-[4-(diethylamino)-2-hydroxybenzoyl]benzoate	Diethylamino hydroxybenzoyl hexyl benzoate (DHHB)	10%	Organic UVA absorber	397.52
33		2-ethoxyethyl (2Z)-2-cyano-2-[3-(3-methoxypropylamino)cyclohex-2-en-1-ylidene]acetate	Methoxypropylamino Cyclohexenylidene Ethoxyethylcyanoacetate	3%	Organic UVA and UVB absorber	322.41
Inorganic UV Filters						
34		Titanium Dioxide/ dioxotitanium	Titanium dioxide and titanium dioxide TiO ₂ (nano)	25%	Inorganic UVB and UVA reflectors	79.87
35		Zinc oxide/ oxozinc	Zinc oxide and zinc oxide (nano) (ZnO)	25%	Inorganic UVB and UVA reflectors	81.38

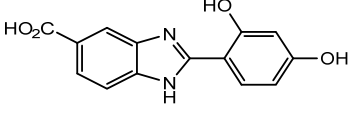
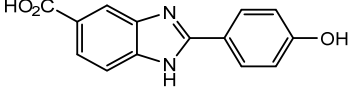
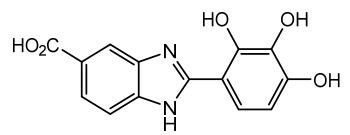
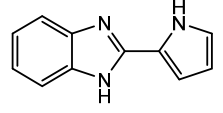
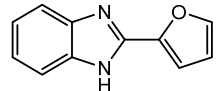
Table S2. Synthetic derivatives with photoprotective and antioxidant activities, as potential UV filters.

Number	Chemical structure	Activity	Values	Reference
57			SPF = 1 λ_c = 382 nm	
58			SPF = 2 λ_c = 390 nm	
59			SPF = 5 λ_c = 340 nm	
60		Photoprotective	SPF = 4 λ_c = 378 nm	[126]
61			SPF = 3 λ_c = 377 nm	
62			SPF = 5 λ_c = 375 nm	
63			SPF = 2 λ_c = 369 nm	
64			SPF = 2 λ_c = 387 nm	
65		Photoprotective	λ_{max} = 275 nm	[127]
		Phototoxicity	PIF = 0.916 – 1.281 (Non-phototoxic)	
66		Photoprotective	λ_{max} = 285 nm	
		Phototoxicity	PIF = 0.920 – 1.00 (Non-phototoxic)	
67		Photoprotective	λ_{max} = 292 nm	
		Phototoxicity	PIF = 2.60 -2.80 (Phototoxic)	
68		Photoprotective	λ_{max} = 275 nm	

		Phototoxicity	PIF = 5.59 – 16.5 (Phototoxic)	
69		Photoprotective	SPF = 16.20 at 3.0×10^{-2} mg/mL λ_{\max} = 323 nm	[128]
70		Photoprotective	SPF = 7.63 at 3.0×10^{-2} mg/mL λ_{\max} = 308 nm	
71		Photoprotective	SPF = 20.60	
72		Photoprotective	SPF = 26.17	[129]
73		Photoprotective	λ_{\max} = 308 nm SPF = 4.74 ± 0.15	
		Antioxidant (DPPH)	2.04 ± 0.15 μ mol Trolox/ mmol	
		Phototoxicity (at 20 μ M and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$77.3 \pm 2.8\%$ and $78.0 \pm 3.5\%$	
74		Photoprotective	λ_{\max} = 313 nm SPF = 9.83 ± 0.64	[130]
		Antioxidant (DPPH)	2145.31 ± 45.8 μ mol Trolox/ mmol	
		Phototoxicity (at 50 μ M and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$77.4 \pm 4.0\%$ and $71.5 \pm 2.5\%$	
		Photostability (solar simulator for 1 hour before repeating HPLC analysis)	94.9%	

75		Photoprotective	$\lambda_{\max} = 315 \text{ nm}$ SPF = 2.22 ± 0.13
		Antioxidant (DPPH)	$2.03 \pm 0.09 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$76.9 \pm 2.0\%$ and $74.3 \pm 3.2\%$
76		Photoprotective	$\lambda_{\max} = 318 \text{ nm}$ SPF = 2.18 ± 0.14
		Antioxidant (DPPH)	$21.41 \pm 0.43 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$79.0 \pm 6.0\%$ and $70.8 \pm 3.9\%$
77		Photoprotective	$\lambda_{\max} = 328 \text{ nm}$ SPF = 5.99 ± 0.12
		Antioxidant (DPPH)	$1362.12 \pm 133.96 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 20 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$18.4 \pm 2.3\%$ and $59.3 \pm 3.4\%$
78		Photoprotective	$\lambda_{\max} = 306 \text{ nm}$
		Antioxidant (DPPH)	$1.67 \pm 0.08 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 20 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$72.8 \pm 2.9\%$ and $74.2 \pm 1.3\%$
79		Photoprotective	$\lambda_{\max} = 311 \text{ nm}$ SPF = 5.20 ± 0.20
		Antioxidant (DPPH)	$1974.58 \pm 16.89 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$62.9 \pm 4.3\%$ and $72.8 \pm 1.0\%$

80		Photoprotective	$\lambda_{\max} = 315 \text{ nm}$ SPF = 3.57 ± 0.23
		Antioxidant (DPPH)	$16.47 \pm 0.54 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$3.7 \pm 0.5\%$ and $1.1 \pm 0.3\%$
81		Photoprotective	$\lambda_{\max} = 315 \text{ nm}$ SPF = 1.96 ± 0.14
		Antioxidant (DPPH)	$0.87 \pm 0.05 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$4.8 \pm 0.6\%$ and $19.8 \pm 2.4\%$
82		Photoprotective	$\lambda_{\max} = 325 \text{ nm}$ SPF = 2.85 ± 0.22
		Antioxidant (DPPH)	$1811.02 \pm 61.7 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$1.2 \pm 0.2\%$ and $45.6 \pm 2.6\%$
83		Photoprotective	$\lambda_{\max} = 317 \text{ nm}$ SPF = 2.21 ± 0.17
		Antioxidant (DPPH)	$1771.82 \pm 84.75 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm ² and UVB 0.5 J/cm ²) in % of viable cells	$74.3 \pm 2.0\%$ and $76.3 \pm 3.6\%$
		Photostability (solar simulator for 1 hour before repeating HPLC analysis)	98.4%

84		Photoprotective	$\lambda_{\max} = 321 \text{ nm}$ $\text{SPF} = 2.85 \pm 0.17$
		Antioxidant (DPPH)	$32.48 \pm 2.38 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm^2 and UVB 0.5 J/cm^2) in % of viable cells	$80.7 \pm 1.3\%$ and $69.0 \pm 0.2\%$
85		Photoprotective	$\lambda_{\max} = 312 \text{ nm}$ $\text{SPF} = 6.01 \pm 0.31$
		Antioxidant (DPPH)	$1.185 \pm 0.02 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm^2 and UVB 0.5 J/cm^2) in % of viable cells	$76.7 \pm 3.4\%$ and $74.2 \pm 3.4\%$
86		Photoprotective	$\lambda_{\max} = 332 \text{ nm}$ $\text{SPF} = 3.69 \pm 0.24$
		Antioxidant (DPPH)	$1241.03 \pm 9.43 \text{ } \mu\text{mol Trolox/ mmol}$
		Phototoxicity (at 50 μM and UVA 20 J/cm^2 and UVB 0.5 J/cm^2) in % of viable cells	$12.2 \pm 1.3\%$ and $60.1 \pm 2.3\%$
87		Photoprotective (1-3% of the compound)	$\text{SPF} = 2.44 - 3.06$ $\lambda_c = 341 - 364 \text{ nm}$
		Antioxidant (DPPH)	% inhibition = 70.00 ± 3.25
88		Photoprotective (1-3% of the compound)	$\text{SPF} = 6.84 - 11.15$ $\lambda_c = 368 - 371 \text{ nm}$
		Antioxidant (DPPH)	% inhibition = 15.46 ± 0.98

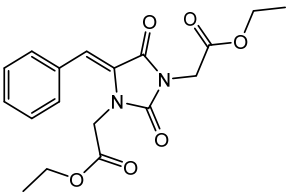
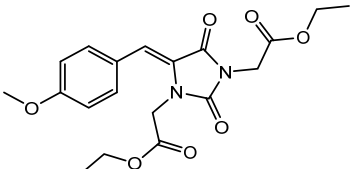
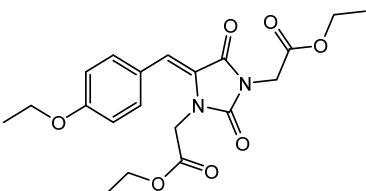
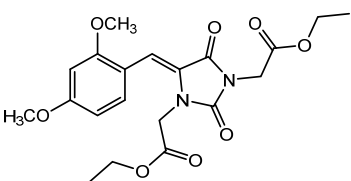
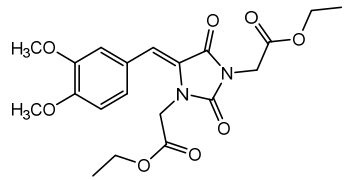
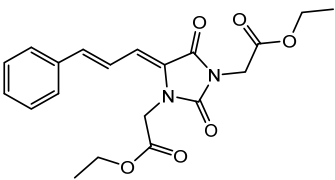
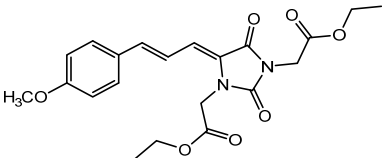
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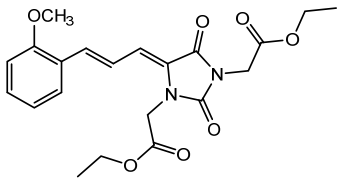
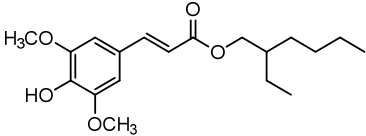
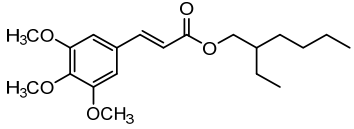
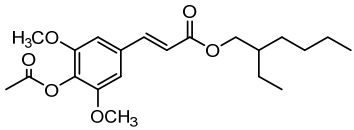
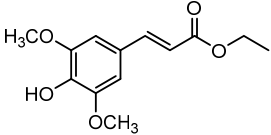
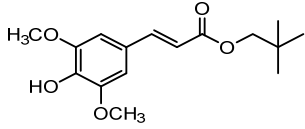
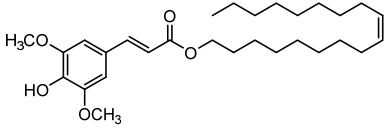
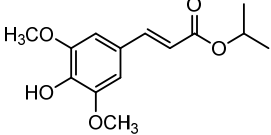
89		Photoprotective (1-3% of the compound)	SPF = 2.41 - 2.79 λ_c = 340 – 344 nm
		Antioxidant (DPPH)	% inhibition = 35.05 ± 0.87
90		Photoprotective	SPF = 9.0 ± 0.1 λ_c = 371 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 2.4 ± 0.7
91		Photoprotective	SPF = 5.0 ± 0.2 λ_c = 365 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 6.1 ± 0.5
92		Photoprotective	SPF = 17.0 ± 0.6 λ_c = 371 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 0.8 ± 0.3
93		Photoprotective	SPF = 4.0 ± 1.7 λ_c = 356 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 6.3 ± 0.7
94		Photoprotective	SPF = 7.0 ± 0.8 λ_c = 363 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 8.2 ± 1.6
95		Photoprotective	SPF = 4.0 ± 0.2 λ_c = 383 nm
		Antioxidant (DPPH) at 400 µM	% inhibition = 3.5 ± 0.4

[25]

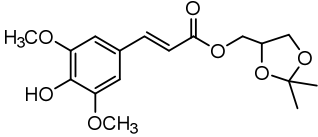
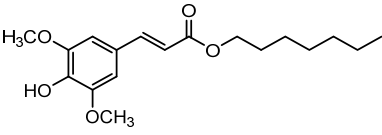
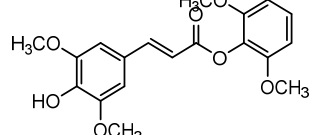
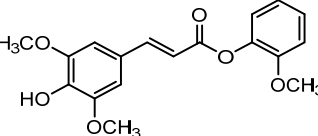
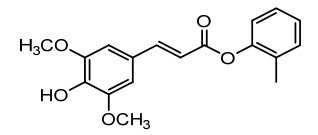
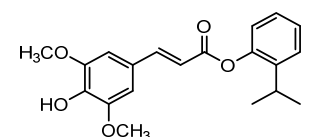
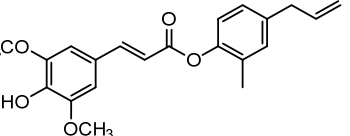
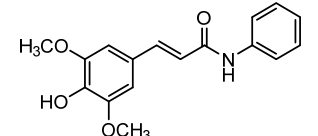
96		Photoprotective	SPF = 14.0 ± 1.7 λ_c = 360 nm
		Antioxidant (DPPH) at 400 μ M	% inhibition = 5.9 ± 0.6
97		Photoprotective	SPF = 3.0 ± 0.2 λ_c = 382 nm
		Antioxidant (DPPH) at 400 μ M	% inhibition = 75.6 ± 0.2
98		Photoprotective	SPF = 4.79 λ_c = 339 nm
99		Photoprotective	SPF = 3.20 λ_c = 363 nm
100		Photoprotective	SPF = 3.16 λ_c = 367 nm
101		Photoprotective	SPF = 2.00 λ_c = 386 nm
		Cytotoxicity (human keratinocytes (K) and human fibroblasts (F))	% cell viability (K) = 93 % cell viability (F) = 105
102		Photoprotective	SPF = 2.50 λ_c = 379 nm
		Cytotoxicity (human keratinocytes (K) and human fibroblasts (F))	% cell viability (K) = 98 % cell viability (F) = 89

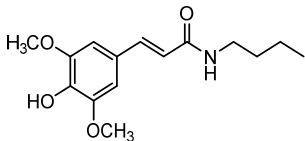
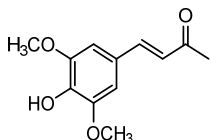
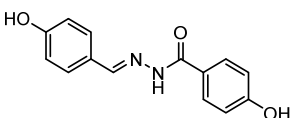
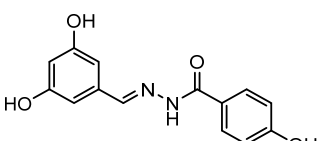
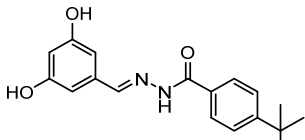
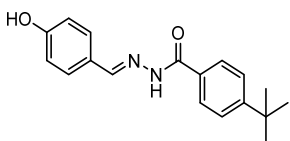
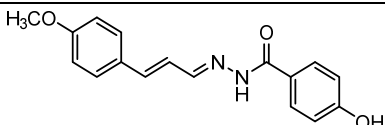
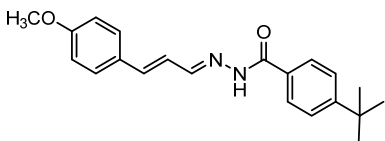
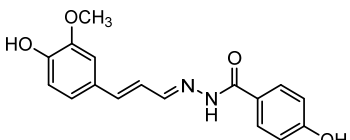
[132]

103		Photoprotective	SPF = 2.97 λ_c = 331 nm
104		Photoprotective Cytotoxicity (human keratinocytes (K) and human fibroblasts (F))	SPF = 3.07 λ_c = 366 nm % cell viability (K) = 95 % cell viability (F) = 107
105		Photoprotective	SPF = 2.49 λ_c = 370 nm
106		Photoprotective	SPF = 1.84 λ_c = 383 nm
107		Photoprotective	SPF = 1.87 λ_c = 382 nm
108		Photoprotective Cytotoxicity (human keratinocytes (K) and human fibroblasts (F))	SPF = 1.87 λ_c = 381 nm % cell viability (K) = 100 % cell viability (F) = 94
109		Photoprotective Cytotoxicity (human keratinocytes (K) and human fibroblasts (F))	SPF = 1.68 λ_c = 391 nm % cell viability (K) = 100 % cell viability (F) = 97

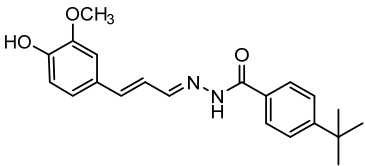
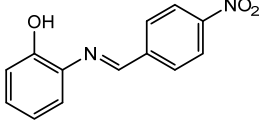
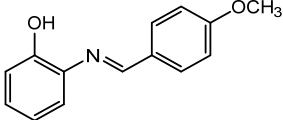
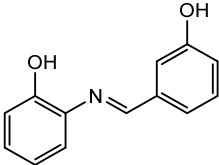
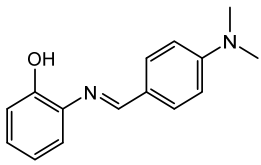
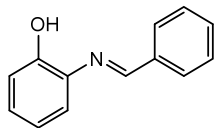
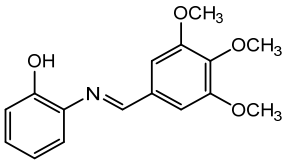
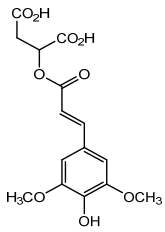
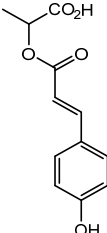
110		Photoprotective	SPF = 1.94 $\lambda_c = 389 \text{ nm}$
111		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 18%
		Antioxidant (DPPH)	IC ₅₀ = 22.2 ± 1.1 nmol
112		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 22%
		Antioxidant (DPPH)	-
113		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 31%
		Antioxidant (DPPH)	-
114		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 26%
		Antioxidant (DPPH)	IC ₅₀ = 18.0 ± 0.9 nmol
115		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 35%
		Antioxidant (DPPH)	IC ₅₀ = 17.0 ± 0.7 nmol
116		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 21%
		Antioxidant (DPPH)	IC ₅₀ = 19.9 ± 1.0 nmol
117		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 52%
		Antioxidant (DPPH)	IC ₅₀ = 14.4 ± 0.4 nmol

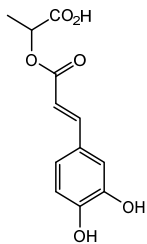
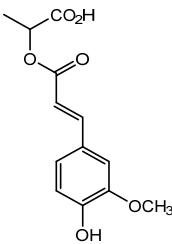
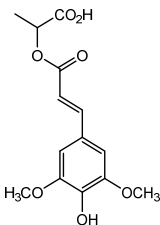
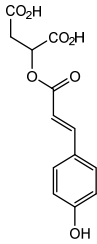
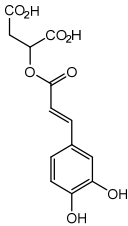
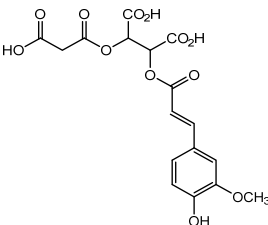
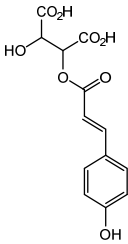
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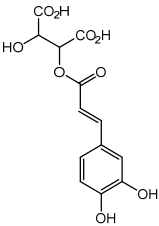
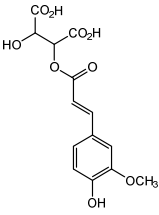
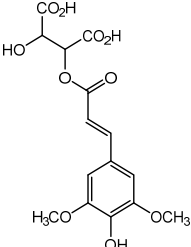
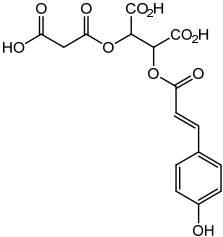
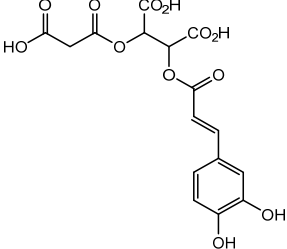
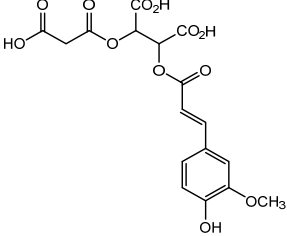
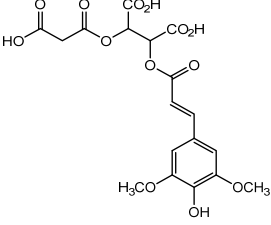
118		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 13%
		Antioxidant (DPPH)	IC ₅₀ = 19.8 ± 1.0 nmol
119		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 26%
		Antioxidant (DPPH)	IC ₅₀ = 20.9 ± 1.1 nmol
120		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 73%
		Antioxidant (DPPH)	IC ₅₀ = 21.1 ± 1.1 nmol
121		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 67%
		Antioxidant (DPPH)	IC ₅₀ = 17.1 ± 0.8 nmol
122		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 70%
		Antioxidant (DPPH)	IC ₅₀ = 15.3 ± 0.5 nmol
123		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 66%
		Antioxidant (DPPH)	IC ₅₀ = 13.7 ± 0.6 nmol
124		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 85%
		Antioxidant (DPPH)	IC ₅₀ = 19.4 ± 0.9 nmol
125		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 20%
		Antioxidant (DPPH)	IC ₅₀ = 8.9 ± 0.3 nmol

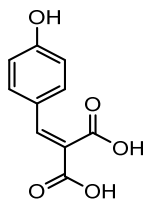
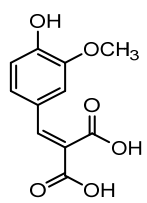
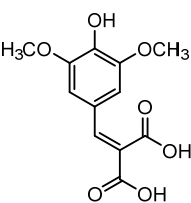
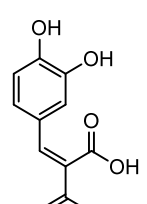
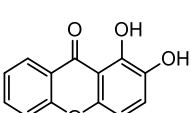
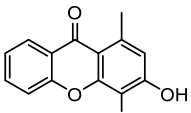
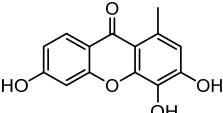
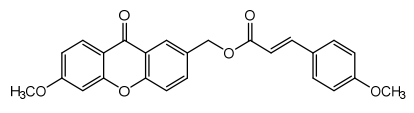
126		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 40%
		Antioxidant (DPPH)	IC ₅₀ = 15.9 ± 0.7 nmol
127		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 45%
		Antioxidant (DPPH)	IC ₅₀ = 9.4 ± 0.4 nmol
128		Antioxidant (DPPH)	IC ₅₀ = 275 µM
		Photoprotective	SPF = 3 λ _c = 376 nm
129		Photoprotective	SPF = 5 λ _c = 368 nm
130		Photoprotective	SPF = 4 λ _c = 366 nm
131		Photoprotective	SPF = 2 λ _c = 379 nm
132		Photoprotective	SPF = 2 λ _c = 388 nm
133		Photoprotective	SPF = 4 λ _c = 386 nm
134		Antioxidant (DPPH)	IC ₅₀ = 88.2 µM
		Photoprotective	SPF = 2 λ _c = 389 nm

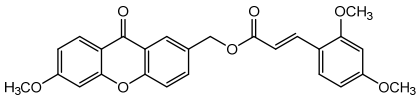
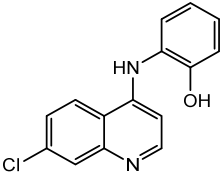
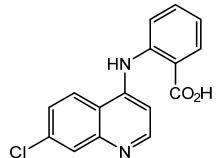
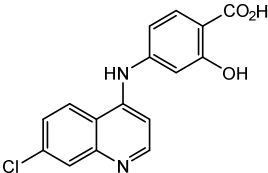
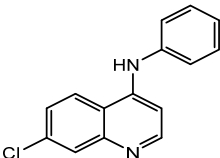
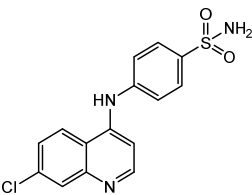
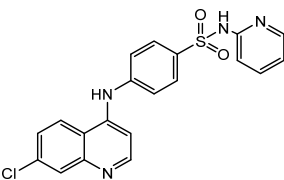
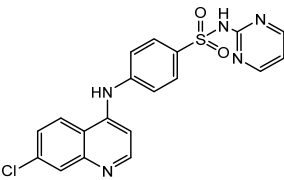
[134]

135		Antioxidant (DPPH)	IC ₅₀ = 109.6 µM	
		Photoprotective	SPF = 2 λ _c = 387 nm	
136		Photoprotective	SPF = 2.0 ± 0.5	
137		Photoprotective	SPF = 10.0 ± 0.2 λ _c = 383 nm	
138		Photoprotective	SPF = 6.0 ± 0.7 λ _c = 389 nm	
139		Photoprotective	SPF = 5.0 ± 0.3 λ _c = 388 nm	[135]
140		Photoprotective	SPF = 6.0 ± 1.1 λ _c = 387 nm	
141		Photoprotective	SPF = 6.0 ± 1.1 λ _c = 387 nm	
142		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 19.1%	[24]
		Antioxidant (DPPH)	IC ₅₀ = 7.9 nmol	
143		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 21.9%	
		Antioxidant (DPPH)	-	

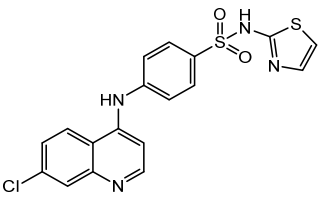
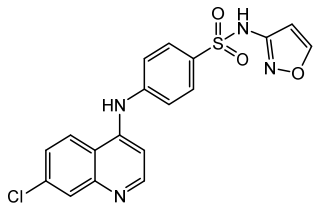
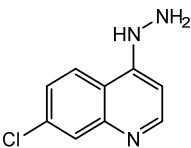
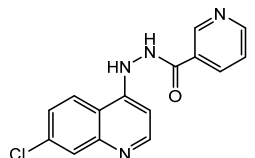
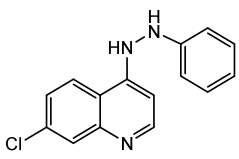
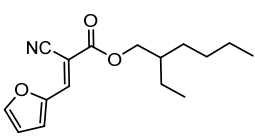
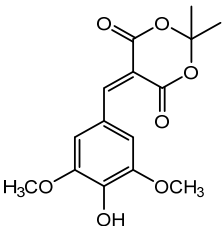
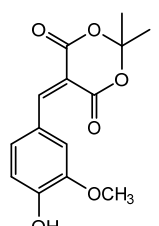
144		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 20.2%
		Antioxidant (DPPH)	IC ₅₀ = 9.9 nmol
145		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 24.4%
		Antioxidant (DPPH)	IC ₅₀ = 13.9 nmol
146		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 26.1%
		Antioxidant (DPPH)	IC ₅₀ = 10.6 nmol
147		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 22.5%
		Antioxidant (DPPH)	-
148		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 31.5%
		Antioxidant (DPPH)	IC ₅₀ = 6.8 nmol
149		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 26.3%
		Antioxidant (DPPH)	IC ₅₀ = 10.2 nmol
150		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 20.2%
		Antioxidant (DPPH)	-

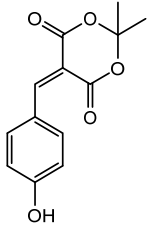
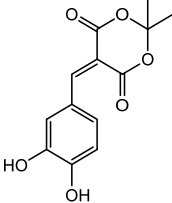
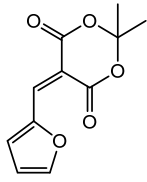
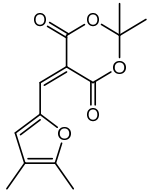
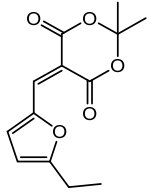
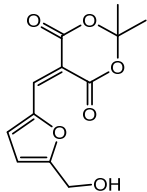
151		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 16.1%
		Antioxidant (DPPH)	IC ₅₀ = 5.2 nmol
152		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 23.2%
		Antioxidant (DPPH)	IC ₅₀ = 11.9 nmol
153		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 24.3%
		Antioxidant (DPPH)	IC ₅₀ = 6.9 nmol
154		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 15.7%
		Antioxidant (DPPH)	-
155		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 15.5%
		Antioxidant (DPPH)	IC ₅₀ = 3.9 nmol
156		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 14.3%
		Antioxidant (DPPH)	IC ₅₀ = 5.5 nmol
157		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 17.4%
		Antioxidant (DPPH)	EC ₅₀ = 4.2 nmol

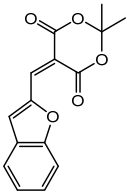
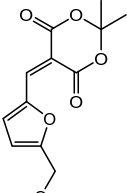
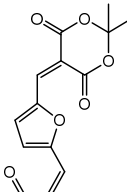
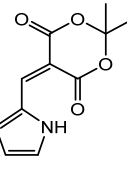
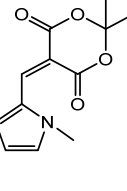
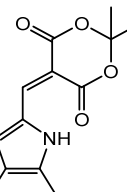
158		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 3.0% λ_{\max} = 314 nm	[137]
		Antioxidant (DPPH)	-	
159		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 1.9% λ_{\max} = 328 nm	
		Antioxidant (DPPH)	IC ₅₀ (nmol) = 20.7	
160		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 8.9% λ_{\max} = 330 nm	[137]
		Antioxidant (DPPH)	IC ₅₀ (nmol) = 3.9	
161		Photoprotective	LoA = 4.9% λ_{\max} = 340 nm	
		Antioxidant (DPPH)	IC ₅₀ (nmol) = 3.0	
162		Phototoxicity	Cell viability = 100% (at 200 μ M in non-radiated and irradiated HaCaT keratinocytes)	[138]
		Antioxidant (DPPH)	IC ₅₀ = 28.4 \pm 0.2 μ M	
163		Antioxidant (DPPH)	IC ₅₀ = 31.2 \pm 4.8 μ M	
164		Antioxidant (DPPH)	IC ₅₀ = 47.3 \pm 0.4 μ M	
165		Photoprotective (1 hour after irradiation with solar light simulator conducted at 500 W/m ²)	λ_{\max} = 303 nm λ_c = 345 SPF = 14.69 Decrease of SPF after irradiation 10.97%	[26]

166		Photoprotective (1 hour after irradiation with solar light simulator conducted at 500 W/m ²)	$\lambda_{\max} = 299, 329 \text{ nm}$ $\lambda_c = 381$ SPF = 19.69 SPF after irradiation = 17.25%
		Phototoxicity (human keratinocytes (K) HaCaT and skin fibroblasts (F)) at concentration of 50 μM	% cell viability (K) = 82 % cell viability (F) = 80
167		Photoprotective	SPF = 4.0 \pm 0.9 $\lambda_c = 387 \text{ nm}$
168		Photoprotective	SPF = 3.0 \pm 0.5 $\lambda_c = 389 \text{ nm}$
169		Photoprotective	SPF = 3.0 \pm 0.1 $\lambda_c = 388 \text{ nm}$
170		Photoprotective	SPF = 4.0 \pm 0.0 $\lambda_c = 385 \text{ nm}$
171		Photoprotective	SPF = 3.0 \pm 0.2 $\lambda_c = 388 \text{ nm}$
172		Photoprotective	SPF = 2.0 \pm 0.3 $\lambda_c = 388 \text{ nm nm}$
173		Photoprotective	SPF = 2.0 \pm 0.1 $\lambda_c = 386 \text{ nm}$

[139]

174		Photoprotective	SPF = 4.0 ± 0.4 λ_c = 385 nm	
175		Photoprotective	SPF = 4.0 ± 0.0 λ_c = 381 nm	
176		Photoprotective	SPF = 11.0 ± 0.1 λ_c = 376 nm	
177		Photoprotective	SPF = 6.0 ± 0.3 λ_c = 377 nm	
178		Photoprotective	SPF = 3.0 ± 0.4 λ_c = 384 nm	
179		Photoprotective	λ_{max} = 339 nm SPF = 17.30 (with 5% of the compound in formulation)	[140]
180		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 11.4%	[141]
		Antioxidant (DPPH)	IC ₅₀ = 19.70 ± 1.00 mM	
		Tyrosinase inhibition	IC ₅₀ = 17 ± 2 μ M	
181		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 9.0%	[141]
		Antioxidant (DPPH)	IC ₅₀ > 400 mM	
		Tyrosinase inhibition	IC ₅₀ = 23 ± 3 μ M	

182		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 3.5%
		Antioxidant (DPPH)	IC ₅₀ > 400 mM
		Tyrosinase inhibition	IC ₅₀ = 106 ± 13 µM
183		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 6.4%
		Antioxidant (DPPH)	IC ₅₀ = 16.70 ± 0.80 mM
		Tyrosinase inhibition	IC ₅₀ = 13 ± 2 µM
184		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 3.5%
		Antioxidant (DPPH)	IC ₅₀ > 400 mM
		Tyrosinase inhibition	IC ₅₀ = 465 ± 56 µM
185		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 4.2%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-
186		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 5.1%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-
187		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 3.4%
		Antioxidant (DPPH)	IC ₅₀ > 400 mM
		Tyrosinase inhibition	-

188		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 28.7%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	IC ₅₀ = 252 ± 30 µM
189		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 12.9%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-
190		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 12.4%
		Antioxidant (DPPH)	IC ₅₀ > 400 mM
		Tyrosinase inhibition	-
191		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 0.1%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-
192		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 3.5%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-
193		Photoprotective (after UV irradiation of 8.32 W/m ² for 1 hour)	LoA = 11.9%
		Antioxidant (DPPH)	-
		Tyrosinase inhibition	-

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