

Repeated short-term exposure to UVR causes erythema of the skin and subsequently activates the melanocytes. This leads to increased tyrosinase activity and melanin production.⁹ As a result, darkening of skin color known as tanning which is a type of hyperpigmentation occurs.⁹ Excessive long-term exposure to UVR leads to premature aging of the skin, immune system suppression, and development of skin cancers such as melanoma skin cancers.^{9,10} Additionally, UVR exposure increases the production of hydrogen peroxide (H_2O_2) and other reactive oxygen species (ROS) during the melanogenesis process, which induce melanocytes to undergo oxidative stress.^{1,3} Consequently, melanin production will be increased due to the formation of ROS, producing key signals that stimulate melanogenesis.⁶ It can be concluded that ROS scavengers and tyrosinase inhibitors can act as antimelanogenesis agents.¹ It is also widely recognized that UV-induced ROS generation plays a role in the pathogenesis of a variety of skin disorders, including aging, wrinkles, photosensitivity, and cancer.¹¹ Several compounds that are melanin inhibitors are utilized widely in cosmetic industries including kojic acid, hydroquinone, ascorbic acid, and arbutin.² These compounds possess antioxidant and antityrosinase activities.¹² However, their use has been limited because they can cause adverse effects on the skin and cytotoxic issues.¹²

Due to increasing health and environmental awareness, many researchers have recently been attempting to develop new natural skin-lightening products that contain phytochemicals, for instance, polyphenol, flavonoids, and carotenoids, to prevent excessive melanogenesis and hyperpigmentation.^{13,14} Various phytochemicals and plant extracts have been discovered to be less toxic and exhibit numerous biological properties.¹⁵ Thus, the studies involving the investigation of antimelanogenesis, antityrosinase, and antioxidant activities of plants are crucial to discovering their potential whitening benefits toward human skin. In this systematic review, the antimelanogenesis, antityrosinase, antioxidant, and other biological activities of various natural plant species for the development of natural product-based skin-lightening agents were summarized. This review provides information on the different extraction methods using various solvent systems to extract bioactive compounds from plant extracts, and the evaluation of their biological activities such as antimelanogenesis, antityrosinase, and antioxidant was reviewed and presented in Table 1.

2. METHODS

Preferred reporting items for systematic review and meta-analyses (PRISMA) were used as a standard to conduct the systematic review. This published standard allowed authors to gather all relevant information and used various inclusion and exclusion criteria to determine the articles that will be included in the review. It also ensures that all components of the research are reported accurately and transparently.¹⁶ Article resources were searched using the Scopus database in May 2022. The first step of the systematic review process involved the development of a search string based on the identification of keywords from my research question and the use of Boolean Operators. The keywords used for this review were based on various plant species with antimelanogenesis and antityrosinase activities to produce a comprehensive review covering most aspects of these two activities, using the search string (“plant” OR “medicinal plant”) AND (“anti-melanogenesis” OR

“anti-tyrosinase”). As a result, a total of 414 records were successfully retrieved from the Scopus database.

No duplicated articles were found, and 414 records were further screened using several inclusion and exclusion criteria. The first criteria was the document type by focusing only on primary source research articles and excluded sources in the form of a review, erratum, book chapter, and conference paper. The second and third criteria were the publication stage and language, respectively, by selecting final articles only in English. Additionally, it should be noted that the timeline was chosen as a 5-year period (2017–2022). Based on these criteria, 181 articles were excluded. It is worth noting that only articles with full text were included. Search engines such as Google, Google Scholar, Elsevier, and ResearchGate were used to download the full texts. The screening stage of the articles was done based on the abstract, which indicates that articles with irrelevant content will be eliminated from this study based on the abstract screening.

After screening, a total of 185 articles were selected for the eligibility assessment process. For the eligibility assessment, the main contents of the articles were assessed thoroughly to ensure that relevant and sufficient information matches with the objectives of the review. Hence, 109 articles were eliminated due to lack of data and insufficient information on the evaluation of biological activities of plants and did not focus on the biological activities of individual plant species but rather a variety of plant species. Finally, the remaining 76 articles were included in the qualitative synthesis as shown in Figure 1.

3.0. RESULTS AND DISCUSSION

Table 1 shows the antimelanogenesis, antityrosinase, antioxidant, and other biological activities of various natural plant species. The plant parts, extraction methods, and biological assays used for investigation of biological activities were also recorded in the table.

Based on the strong evidence of biological activities of plant extracts, the studies that focus on the determination of melanin content, tyrosinase inhibition, and antioxidant activity can identify natural plants with potent depigmenting effects. To investigate the antimelanogenesis activity, the quantification analysis of melanin contents was measured using a specific melanoma cell line, while mushroom tyrosinase activity and cellular tyrosinase activity assays were generally used to evaluate antityrosinase activity. In addition, there were a variety of assays such as DPPH, ABTS, CUPRAC, and FRAP that can be performed to examine the antioxidant activity of plant extracts. Other biological activities including antiaging, antidiabetic, and anti-inflammatory activities also have been identified from the plant extracts.

3.1. Extraction Methods. Extraction is the crucial first step in the analysis of natural plants because it is important to extract the desired bioactive compounds from the plant materials for further separation and characterization.¹⁷ Different solvent systems are available to extract the bioactive compounds from plants, and the solvent is chosen based on the polarity of the solute of interest.^{17,18} The solute will dissolve properly in a solvent with polarity identical to the solute.¹⁸ Solvents such as ethanol, methanol, ethyl acetate, water, chloroform, acetone, acetonitrile, dichloromethane, and butanol or nonpolar solvents such as hexane, benzene, and petroleum ether are commonly employed for extraction. In particular, ethanol and water are the most popular solvents used by biologists for extraction due to their lower toxicity and effectiveness in extracting bioactive compounds. However,

Table 1. Extraction Method, Biological Assays, Antimelanogenesis, Antityrosinase, and Other Biological Activities^a

Plant name	Parts	Sample preparation and extraction methods	Results					References
			Biology assays	Antimelanogenesis	Antityrosinase	Antioxidant:	Others	
<i>Acanthus ilicifolius</i>	Leaves	Sample preparation: Leaves were freeze-dried, grinded into fine powders, and subjected to extraction and purification	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	NR	-Arbutin as positive control	Antioxidant:	24	
		Solvent extraction: 70% acetone–water	Antioxidant: DPPH, ABTS, and FRAP assays	-Tyrosinase inhibition IC ₅₀ : CTs: 19.7 ± 0.13 μg/mL	a) DPPH assay: -Ascorbic acid as standard			
<i>Achillea biebersteinii</i>	Flowers	Extracted crude extract separated by column chromatography, which first eluted with methanol–water and then 70% acetone–water to obtain condensed tannins (CTs) Temperature: 25 °C	Antimelanogenesis: Melanin content assay using B16F10 murine melanoma cells	-Fractions 25 and 27 obtained from extracts using ASE decreased the melanin release from B16F10 cells	-Kojic acid as positive control	Antioxidant:	25	
		Solvent extraction: Distilled H ₂ O, 75% EtOH, 50% EtOH, 25% EtOH	Antityrosinase: Mushroom tyrosinase inhibitory assay using L-DOPA as a substrate	Antioxidant: DPPH assay	-EC ₅₀ (μg/mL): CTs: 104 ± 0.894 Ascorbic acid: 131.47 ± 1.90 b) ABTS assay: -Ascorbic acid as standard -EC ₅₀ (μg/mL): CTs: 86 ± 0.616 Ascorbic acid: 119.97 ± 0.463 c) FRAP assay: -Ascorbic acid as standard -EC ₅₀ (mg AAE/g): CTs: 758.28 ± 2.42 Ascorbic acid: NR	-Vitamin C as standard		-Extracts obtained by UAE. SE had better antioxidant activity than extracts obtained by ACE and M

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Achillea filipendulina</i>	Flower, leaves	Isolation of essential oil: Flowers and leaves subjected to hydrodistillation, and essential oil (EO) was collected	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate	NR	tyrosinase inhibitory activity. Hence, this extract was fractionated, with fractions 5, 6, and 7 showing 34.9, 24.3, and 31.5% inhibitory activity, respectively		26
					Murine tyrosinase activity: Fractions 25 and 27 showed significant murine tyrosinase inhibitory activity with approximately 80%		
					-Kojic acid as positive control	Antioxidant:	
		Extraction method: maceration technique using EtOH	Antioxidant: DPPH, ABTS, and PM assays, metal chelating activity α-amylase, α-glucosidase, and cholinesterase inhibition: α -amylase, α -glucosidase and cholinesterase inhibition assays		-Tyrosinase inhibition (mg KAE/g extract): Flowers-EtOH: 23.97 $\pm$ 0.84	a) DPPH assay (mg TE/g extract): Flowers-EtOH: 53.93	
					Leaves-EtOH: 24.41 $\pm$ 0.95 Flower-EO: NR Leaves-EO: NR	Leaves-EtOH: 51.70 Flower-EO: 25.87 Leaves-EO: 22.13 b) ABTS assay (mg TE/g extract): Flowers-EtOH: 43.47 Leaves-EtOH: 35.03 Flower-EO: 18.23 Leaves-EO: 15.40 c) PM assay (mg AAE/g extract): Flowers-EtOH: 84.03 Leaves-EtOH: 70.17	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Aerva lanata</i> L. Juss	Herb	Solvent extraction: 50% EtOH, 80% EtOH, 100% EtOH, H ₂ O	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	NR	-Kojic acid as positive control	Flower-EO: NR	
						Leaves-EO: NR	
						d) Metal chelating assay: (mg EDTAE/g extract):	
						Flowers-EtOH: 37.13	
						Leaves-EtOH: 30.47	
						Flower-EO: NR	
						Leaves-EO: NR	
						α -amylase inhibition (mmol ACE/g extract):	
						Flowers-EtOH: 1.91 $\pm$ 0.05	
						Leaves-EtOH: 1.75 $\pm$ 0.05	
						Flower-EO: 0.71 $\pm$ 0.04	
						Leaves-EO: 0.48 $\pm$ 0.02	
						α -glucosidase inhibition (mmol ACE/g extract):	
						Flowers-EtOH: 2.84 $\pm$ 0.04	
						Leaves-EtOH: 2.97 $\pm$ 0.06	
						Flower-EO: 0.98 $\pm$ 0.03	
						Leaves-EO: 1.10 $\pm$ 0.07	
						Cholinesterase inhibition (mg GALAE/g extract):	
						AChE inhibition:	
						Flowers-EtOH: 2.46 $\pm$ 0.06	
						Leaves-EtOH: 2.31 $\pm$ 0.05	
						Flower-EO: 1.41 $\pm$ 0.07	
						Leaves-EO: 0.94 $\pm$ 0.06	
						BChE inhibition:	
						Flowers-EtOH: 3.65 $\pm$ 0.07	
						Leaves-EtOH: 2.83 $\pm$ 0.05	
						Flower-EO: 1.90 $\pm$ 0.04	
Leaves-EO: 1.28 $\pm$ 0.09							
Antioxidant:							
						27	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
		Temperature: 60 °C, 80 °C, 100 °C, 180 °C	Antioxidant: DPPH, ABTS, metal-chelating activity, oxygen radical absorbance (ORAC) assays		-Tyrosinase inhibition EC ₅₀ (μg/mL):	a) DPPH assay (mg TE/g):	
			Antielastase: Elastase inhibition assay		100% EtOH:	100% EtOH:	
			Anticollagenase activity: Collagenase inhibition assay		60 °C: 46.48 ± 2.93	60 °C: 10.07 ± 0.23	
					180 °C: 52.19 ± 2.84	80 °C: 9.17 ± 0.07	
					80% EtOH:	100 °C: 10.28 ± 0.46	
					60 °C: 43.32 ± 0.57	180 °C: 72.48 ± 0.91	
					180 °C: 60.10 ± 0.44	80% EtOH:	
					50% EtOH:	60 °C: 19.86 ± 0.01	
					60 °C: 46.08 ± 0.29	80 °C: 18.02 ± 0.09	
					180 °C: 58.56 ± 0.37	100 °C: 48.43 ± 1.60	
					H ₂ O:	180 °C: 119.85 ± 1.95	
					60 °C: 155.97 ± 1.34	50% EtOH:	
					180 °C: 124.62 ± 1.14	60 °C: 24.84 ± 0.52	
					Kojic acid: 28.42 ± 0.11	80 °C: 23.28 ± 0.00	
						100 °C: 24.28 ± 1.18	
						180 °C: 82.63 ± 0.90	
						H ₂ O:	
						60 °C: 15.22 ± 0.71	
						80 °C: 16.27 ± 0.67	
						100 °C: 21.71 ± 0.94	
						180 °C: 79.94 ± 1.12	
						b) ABTS assay (mg TE/g):	
						100% EtOH:	
						60 °C: 9.90 ± 0.01	
						80 °C: 12.77 ± 0.00	
						100 °C: 12.31 ± 0.21	
						180 °C: 98.94 ± 1.75	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
						80% EtOH: 60 °C: 11.60 ± 0.10 80 °C: 14.37 ± 0.28 100 °C: 50.22 ± 0.36 180 °C: 107.58 ± 1.32 50% EtOH: 60 °C: 34.72 ± 0.80 80 °C: 36.11 ± 1.06 100 °C: 33.61 ± 0.83 180 °C: 81.16 ± 3.81 H ₂ O: 60 °C: 38.61 ± 0.48 80 °C: 42.16 ± 0.34 100 °C: 34.57 ± 1.88 180 °C: 88.12 ± 1.26 c) Metal chelating activity: EC ₅₀ (mg/mL): 100% EtOH: 60 °C: 1.58 ± 0.17 180 °C: 5.30 ± 0.70 80% EtOH: 60 °C: 3.42 ± 0.06 180 °C: 5.10 ± 0.01 50% EtOH: 60 °C: 2.59 ± 0.18 180 °C: 3.70 ± 0.08 H ₂ O: 60 °C: na 180 °C: na d) ORAC assay (mM TE/g): 100% EtOH: 60 °C: 0.36 ± 0.06 180 °C: 1.85 ± 0.19 80% EtOH:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
						60 °C: 0.93 ± 0.20	
						180 °C: 2.35 ± 0.18	
						50% EtOH:	
						60 °C: 0.90 ± 0.30	
						180 °C: 3.84 ± 0.06	
						H₂O:	
						60 °C: 0.81 ± 0.09	
						180 °C: 2.32 ± 0.20	
						Antielastase:	
						-Epigallocatechin gallate as positive control	
						EC ₅₀ (mg/mL):	
						100% EtOH:	
						60 °C: na	
						180 °C: 57.26 ± 0.30	
						80% EtOH:	
						60 °C: 95.25 ± 1.26	
						180 °C: 22.54 ± 1.86	
						50% EtOH:	
						60 °C: 153.82 ± 2.88	
						180 °C: 35.81 ± 0.81	
						H₂O:	
						60 °C: na	
						180 °C: 166.23 ± 5.42	
						Anticollagenase:	
						-Epigallocatechin gallate as positive control	
						EC ₅₀ (mg/mL):	
						100% EtOH:	
						60 °C: 598.23 ± 2.65	
						180 °C: 78.47 ± 0.29	
						80% EtOH:	
						60 °C: 129.44 ± 0.49	
						180 °C: 59.73 ± 0.31	
						50% EtOH:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Allium ursinum</i>	Leaves	Solvent extraction: H ₂ O, 70% EtOH, 100% EtOH Temperature: 40 °C	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate Antioxidant: DPPH assay	NR	-Kojic acid as positive control	60 °C: 158.08 ± 3.61 180 °C: 21.76 ± 1.27 H₂O: 60 °C: 63.07 ± 14.08 180 °C: 134.32 ± 3.20 Antioxidant:	28
						A) DPPH assay: -Ascorbic acid as standard SC ₅₀ (values of active DPPH scavengers): H ₂ O: 0.471 mg/mL 70% EtOH: 0.532 mg/mL 100% EtOH: 0.643 mg/mL Ascorbic acid: 0.008 μ/mL Antioxidant:	
<i>Aronia melanocarpa</i>	Stems	Solvent extraction: H ₂ O Temperature: 130 °C	Antityrosinase: Dopachrome method using L-DOPA as a substrate Antioxidant: DPPH and reducing power assays Enzyme inhibitory activity: α-amylase and α-glucosidase were evaluated using Caraway-Somogyi iodine/potassium iodide (IKI) and 4-N-trophenyl-α-D-glucopyranoside method respectively	NR	-Kojic acid as positive control -Tyrosinase inhibition of H ₂ O extract (mg KAE/g extract): 15.87 ± 3.82	a) DPPH assay: -IC ₅₀ of H ₂ O extract: 0.10 ± 0.02 mg/mL	29
						b) Reducing power assay:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Artemisia asiatica</i>	NR	Preparation: 95% EtOH extract was purchased	Antimelanogenesis: Melanin formation assays using B16F10, a melanoma cell line	-Arbutin as positive control	-Arbutin as positive control	-IC ₅₀ of H ₂ O extract: 1.25 ± 0.03 mg/mL Antidiabetic activity: a) α -amylase inhibition (mmol ACAE/g extract): 0.59 ± 0.01 -Acarbose as standard b) α -glucosidase (mmol ACAE/g extract): 7.50 ± 0.32 -Acarbose as standard	30
			Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate and cellular tyrosinase activity assay in B16F10 cells	-EtOH extract suppressed melanin secretion and decreased the melanin content in α -MSH-stimulated B16F10 cells in a dose-dependent manner	-EtOH extract inhibited the mushroom tyrosinase and cellular tyrosinase activity in a dose-dependent manner and had a stronger tyrosinase inhibitory effect than arbutin		
<i>Artemisia capillaris</i>	NR	Solvent extraction: 100% EtOH with concentrations of 0, 6.25, 12.5, 25, 50 μ g/mL	Antimelanogenesis: Melanin content assay using B16F10 mouse melanoma cells	-EtOH extract reduced the cellular melanin content in a dose-dependent manner in α -MSH-stimulated B16F10 cells, with a 40.24% inhibition at 50 μ g/mL	-EtOH extract significantly decreased cellular tyrosinase activity in a dose-dependent manner, with a 30.92% inhibition at 50 μ g/mL		31
			Antityrosinase: Cellular tyrosinase activity assay in B16F10 cells				
<i>Asparagus cochinchinensis</i>	Roots	Solvent extraction and preparation: 25% EtOAc and fermentation	Antimelanogenesis: Melanin content assay using HEMs and A375.S2	Fermented and unfermented extracts inhibit melanogenesis in HEMs and A375.S2 in a	-Kojic acid and α -arbutin as positive controls	Antioxidant:	32

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis dose-dependent manner	Antityrosinase	Others	
<i>Aurea helianthus</i>		Temperature: 40 °C	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate and cellular tyrosinase activity assay in HEMs and A375.S2	a) Mushroom tyrosinase activity:	A) DPPH assay:		
			Antioxidant: DPPH and reducing power assays	-IC ₅₀ (mg/L):	-BHT as standard		
				Fermented extracts: 50.6 ± 3.1 Unfermented extracts: 527.3 ± 23.6 Kojic acid: 18.6 ± 0.5 α-arbutin: 261.4 ± 12.8	-IC ₅₀ (mg/L): Fermented extracts: 250.6 ± 32.5 Unfermented extracts: 586.9 ± 86.1 BHT: 105.3 ± 285.6 mg/L		
				b) Cellular tyrosinase activity (% of inhibition): Fermented extracts: 48.6% ± 1.8% – 55.8% ± 2.3% Unfermented extracts: 3.6% ± 2.0% – 28.4% ± 1.3%	B) Reducing power assay: -BHA, ascorbic acid, α-tocopherol as standards -IC ₅₀ (mg/L): Fermented extracts: 25.7 ± 3.5 Unfermented extracts: 59.0 ± 6.2 BHA: 35.4 ± 2.6 Ascorbic acid: 76.8 ± 6.2 α-tocopherol: 53.2 ± 3.7		
	Stem	Solvent extraction: EtOH Temperature: 60 °C	Antimelanogenesis: Melanin content assay using B16 melanoma cells	The extract reduced the melanin content by 20% in α-MSH-stimulated B16 melanoma cells	NR The extract inhibited the tyrosinase activity in a dose-dependent manner	4	
			Antityrosinase: Cellular				

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Beta vulgaris</i> subsp. <i>Maritima</i> (L.) Arcang.	Aerial parts	Preparation: Aerial parts subjected to hydro distillation and essential oil was collected	tyrosinase activity assay in B16 cells				
			Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosinase as a substrate	NR	-Kojic acid as positive control	Antioxidant:	33
			Antioxidant: DPPH (2,2-Diphenyl-1-picrylhydrazyl) radical scavenging assay, ABTS (2,2'-azino-bis-3-azoline-6-sulfonic acid) radical scavenging assay, reducing power assay, catalase activity, paraoxonase activity (PON1)		-Tyrosinase Inhibition rate (%);	a) DPPH assay:	
			Anticholinesterase activity: Colorimetric method		Essential oil: 67	-BHT as standard	
					Kojic acid: 85	-IC ₅₀ (mg/mL): Essential oil: 0.055 ± 0.006 BHT: 0.018 ± 0.010 b) ABTS assay: -BHT as standard -IC ₅₀ (mg/mL): Essential oil: 0.079 ± 0.010 BHT: 0.050 ± 0.0 c) Reducing power assay: -BHT as standard -IC ₅₀ (mg/mL): Essential oil: 0.120 ± 0.002 BHT: 0.020 ± 0.010	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Camellia oleifera</i> Abel	Shell	Solvent extraction: MeOH, H ₂ O, 1,3-butanediol Temperature: 50 °C	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	NR	-Kojic acid as positive control	d) Catalase activity (u/mg protein): - Vitamin C as standard - Essential oil: 524.447 ± 2.58 - Vitamin C: 757.575 ± 0.002 e) PON1 activity (μM/min/L) - Ascorbic acid as standard - Essential oil: 55.0 ± 1.5 - Ascorbic acid: 55.0 ± 0.2 Anticholinesterase activity: - Galantamine as standard - IC ₅₀ (μg/mL): Essential oil: 36 ± 5 Galantamine: 0.38 ± 0.002 NR	34
						-Tyrosinase inhibition rate (%): 1,3-butanediol extract: 71.9 MeOH extract: 49.2 H ₂ O extract: 39.3 -Kojic acid as positive control	
<i>Carapa procera</i>	Leaves, stem, bark	Extraction method (solvent extraction, temperature): Maceration (MeOH, 25 °C), infusion (boiling water, 100 °C)	Antityrosinase: Tyrosinase inhibition assay Antioxidant: DPPH, ABTS, CUPRAC, FRAP, metal chelating, PM assays	NR	-Tyrosinase inhibition (mg KAE/g extract): Leaves: 73.43 ± 0.07	Antioxidant: -Trolox and EDTA as standard -In general, MeOH extract of stem bark had the highest antioxidant activity in all tested assays with 3.14 ± 0.01 mmol TE/g of ABTS assay, 4.47 ± 0.07 mmol TE/g of assay, and 2.15 ± 0.01 mmol TE/g of FRAP assay	35
						Cholinesterase inhibition (mg GALAE/g): Stem barks: 75.25 ± 0.20	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Celastrus hindsii</i>	Leaves	Solvent extraction: MeOH Extracted crude extract separated into: hexane, H ₂ O, EtOAc extract Separated extracts were further fractionated, and the fractions were combined to run column chromatography a second time. α -Amyrin and β -Amyrin were identified through gas chromatography–mass spectrometry Temperature: 25 °C	Biology assays α -glucosidase, and cholinesterase inhibition assays	NR	-Kojic acid as positive control -Tyrosinase inhibition IC ₅₀ (μ g/mL): α -Amyrin and β -amyrin: 178.85 $\pm$ 3.28 Kojic acid: 15.55 $\pm$ 2.28	-Catechin as positive control AChE inhibition: Leaves: 2.55 $\pm$ 0.02 Stem bark: 2.54 $\pm$ 0.01 BChE inhibition: Leaves: 4.16 $\pm$ 0.26 Stem bark: 4.58 $\pm$ 0.13 α-glucosidase and α-amylase inhibition: -Acarbose and galantamine as positive control for α -glucosidase and α -amylase inhibition assays, respectively -MeOH extract of both plant parts exhibits moderate inhibitory activity against α -glucosidase (0.95 $\pm$ 0.01 mmol ACAE/g) and high inhibitory activity against α -amylase (0.77 $\pm$ 0.01 mmol ACAE/g) Antioxidant:	36

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Cinnamomum camphora</i>	Leaves, branches	Solvent extraction: First ultrasonically extracted with acetone aqueous solution and then extracted by PE and EtOAc	Antityrosinase: Monophenolase and diphenolase activity assay	NR	-Tyrosinase monophenolase inhibition IC_{50} ($\mu\text{g/mL}$): Leaves: 167 ± 18 Branches: 268 ± 24	- IC_{50} ($\mu\text{g/mL}$): α -Amyrin and β -Amyrin: 155.28 ± 1.01 BHT: 53.40 ± 1.52 Antioxidant:	37
		Proanthocyanidins (PAs) were obtained after several steps of extraction	Antioxidant: DPPH, ABTS, and FRAP assays			a) DPPH assay: -Vitamin C as standard - IC_{50} ($\mu\text{g/mL}$): Leaves: 78 ± 13 Branches: 274 ± 28 Vitamin C: 72.9 ± 0.5 b) ABTS assay: -Vitamin C as standard - IC_{50} ($\mu\text{g/mL}$): Leaves: 117 ± 16 Branches: 230 ± 30 Vitamin C: 74 ± 9 c) FRAP assay: - IC_{50} ($\mu\text{g/mL}$): Leaves: 4.7 ± 0.5 Branches: 3.6 ± 0.4 Antioxidant:	
<i>Citrus junos</i>	Leaves, flowers, seeds	Preparation: Transfer of explants into a medium to generate yellow callus extract with concentrations of 0, 50, 100, 500, 1000 $\mu\text{g/mL}$	Antimelanogenesis: Melanin content assay using B16F10, a melanoma cell line	-Arbutin as positive control	Callus extract showed inhibition of tyrosinase activity in a dose-dependent manner.		38
			Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	-1000 $\mu\text{g/mL}$ of callus extract showed a $59.3 \pm 4.20\%$ inhibition of melanogenesis, which was stronger than arbutin.		a) DPPH assay:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Clausena indica</i>	Roots	Solvent extraction: MeOH Extracted crude extract fractioned into: EtOAc, hexane EtOAc extract was subjected to column chromatography to produce 5 fractions (Rel–ReS). Three compounds (dentatin, nordentatin, clausine K) were isolated from 5 fractions	Antioxidant: DPPH assay			-Ascorbic acid as standard -1000 $\mu\text{g/mL}$ of callus extract exhibited $68.5 \pm 9.49\%$ of DPPH free radical scavenging ability, which was comparable to 125 μM of ascorbic acid ($62.3 \pm 1.78\%$). Antioxidant:	39
			Antityrosinase: Tyrosinase inhibitory assay using L-tyrosine as a substrate	NR	-Myricetin as positive control		
			Antioxidant: DPPH, ABTS, and lipid peroxidation inhibitory (LPI) assays		-Tyrosinase inhibition IC_{50} ($\mu\text{g/mL}$): a) DPPH assay:		
					Dentatin: NR	-BHT as standard	
					Nordentatin: NR Clausine K: 179.5 Myricetin: 735.6	- IC_{50} ($\mu\text{g/mL}$): Dentatin: NR Nordentatin: 49.2 ± 0.5 Clausine K: 2197.8 ± 53.3 BHT: 16.0 ± 0.2	
						b) ABTS assay: -BHT as standard - IC_{50} ($\mu\text{g/mL}$): Dentatin: NR Nordentatin: 69.9 ± 1.1 Clausine K: 5264.0 ± 164.0 BHT: 82.8 ± 1.1	
						c) LPI assays: -BHT as standard -LPI (%): Dentatin: $37.9 \pm 0.8\%$ Nordentatin: $69.8 \pm 0.4\%$ Clausine K: $60.6 \pm 1.1\%$	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Cosmos caudatus</i> Kunth	Leaves	Solvent extraction: H ₂ O	Antityrosinase: Antityrosinase assay using l-tyrosine as a substrate	NR	-Kojic acid as positive control	BHT: 82.7 ± 0.3%	40
			Antioxidant: DPPH and ABTS assays		-Tyrosinase inhibition IC ₅₀ (μg/mL): H ₂ O extract: 693.2 Kojic acid: 77.8	Antioxidant: a) DPPH assay: -Trolox as standard -IC ₅₀ (μg/mL): H ₂ O extract: 163.6 Trolox: 3.32 b) ABTS assay: -Trolox as standard -IC ₅₀ (μg/mL): H ₂ O extract: 57.2 Trolox: 6.51	
<i>Cymbidium</i> sp. (Orchidaceae)	Flowers, leaves, pseudobulbs, roots	Solvent extraction: CH ₂ Cl ₂ , EtOAc, EtOH/H ₂ O with concentrations of 75, 150, 300 μg/mL	Antityrosinase: Dopachrome method using l-DOPA as a substrate	NR	-Kojic acid as positive control	Antioxidant:	41
			Antioxidant: DPPH assay Collagenase inhibitory activity: Collagenase assay		-Tyrosinase inhibition rate (%) at 300 μg/mL: -CH ₂ Cl ₂ extracts of any plant parts were not active	a) DPPH assay: -Gallic acid as positive control	
					EtOAc: Pseudobulb: 54.19 ± 3.72 Roots: 37.50 ± 2.54 Flowers: 28.29 ± 2.93 EtOH/H ₂ O: Pseudobulb: 64.11 ± 2.34 Roots and Flowers: na	-IC ₅₀ (μg/mL): Flowers: CH ₂ Cl ₂ : na EtOAc: na EtOH/H ₂ O: na Leaves: CH ₂ Cl ₂ : na EtOAc: na EtOH/H ₂ O: na Pseudobulbs:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Cyrtinus hypocistis</i>	Whole plant, petals, stalks, nectar	Solvent extraction: 80:20 EtOH/H ₂ O	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate Antioxidant: OxHLIA (oxidative hemolysis inhibition), TBARS (Thiobarbituric acid reactive substance) assays Antidiabetic: α -glycosidase inhibitory assay Anti-inflammatory: Nitric acid production was assessed using LPS-stimulated RAW 264. Seven macrophages	NR	-Kojic acid as positive control	CH ₂ Cl ₂ : 165.78 EtOAc: 114.18 EtOH/H ₂ O: 233.32 Roots: CH ₂ Cl ₂ : 174.61 EtOAc: 127.17 EtOH/H ₂ O: 304.02 Collagenase inhibitory activity: EtOAc extract of pseudobulbs and roots displayed 4.01 $\pm$ 1.32% and 82.79 $\pm$ 1.60% inhibition of collagenase at 75 μ g/mL. It exhibited high inhibitory activity	42
						Antioxidant:	
					-Tyrosinase inhibition IC ₅₀ (mg/mL):	a) OxHLIA	
					Whole plant extract (CH): 0.20 $\pm$ 0.01	-Trolox as standard	
					Petals extract (PCH): 0.19 $\pm$ 0.01	-IC ₅₀ (ng/mL):	
					Stalks extract (SCH): 0.09 $\pm$ 0.02	CH: 285 $\pm$ 4	
					Nectar extract (NCH): 27.6 $\pm$ 0.7	PCH: 279 $\pm$ 5	
					Kojic acid: 0.078 $\pm$ 0.001	SCH: 306 $\pm$ 2	
						NCH: 672 $\pm$ 15	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biological assays	Antimelanogenesis	Antityrosinase	Others	
<i>Dalea pазensis</i> Rusby	Roots	Solvent extraction: Benzene Extracted crude extract fractioned into: <i>n</i> -hexane/EtOAc, chloroform/EtOH and benzene/EtOAc to yield 4 compounds which are pazentin A (1), pazentin B (2), 4'-hydroxy-2'-3-methoxy-5'-(1''',1''-dimethylallyl)-8-prenylpinocembrin (3) and 2',4'-dihydroxy-4 5'-(1''',1''-dimethylallyl)-8-prenylpinocembrin (4)	Antimelanogenesis: Melanin content assay using B16 murine melanoma cells	-Kojic acid as positive control - Melanin inhibition IC ₅₀ :	-Kojic acid as positive control Mushroom tyrosinase activity assay:	Trolox: 20384 ± 36 b) TBARS -Trolox as standard -IC ₅₀ (ng/mL): CH: 413 ± 9 PCH: 342 ± 2 SCH: 634 ± 12 NCH: 551 ± 13 Trolox: 5389 ± 320 Antidiabetic activity: -Acarbose as positive control -IC ₅₀ (mg/mL): CH: 0.040 ± 0.001 PCH: 0.046 ± 0.004 SCH: 0.039 ± 0.001 NCH: 0.214 ± 0.005 Acarbose: 0.83 ± 0.02 Anti-inflammatory: -Dexamethasone as positive control -IC ₅₀ (μg/mL): CH: 136 ± 11 PCH: 127 ± 8 SCH: 127 ± 12 NCH: 277 ± 14 Dexamethasone: 16 ± 1 NR	43

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Dendropanax morbiiferus</i> H. Lev	Leaves	Temperature: 25 °C	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosinase as a substrate and intracellular tyrosinase inhibition assay in B16 cells	Compound 1 (0.75 ± 0.2 μM) > Compound 4 (1.0 ± 0.4 μM) > Compound 2 and 3 (5.0 ± 1.0 μM and 5.0 ± 1.8 μM)	-IC ₅₀ (μM):		
				Compound 1 and 2:0			
				Compound 3: 49.80 ± 0.09			
				Compound 4: 2.32 ± 0.06			
				Kojic acid: 4.93 ± 0.01			
				Intracellular tyrosinase inhibition assay:			
				-% Intracellular tyrosinase inhibition:			
				Compound 4: 34.2 ± 0.2%			
				Compound 1, 2, and 3: 0%			
				Kojic acid: 45.4 ± 0.1			
<i>Dimocarpus longan Lour.</i> (Longan)	Barks	Temperature: 100 °C	Antimelanogenesis: Melanin content assay using B16F10 melanoma cells Antityrosinase: Intracellular tyrosinase activity assay in B16F10 cells	-Arbutin as positive control		NR	
<i>Dimocarpus longan Lour.</i> (Longan)	Barks	Sample preparation: Powders of longan bark were obtained using a vacuum freeze-drying machine	Antimelanogenesis: Melanin content assay using B16 mouse melanoma cells Antityrosinase: Monophenolase and diphenolase activity assay and intracellular tyrosinase	200 μg/mL of condensed tannins decreased the melanin content of B16 cells to 45.2 ± 1.3%	- Monophenolase IC₅₀:	NR	
<i>Dimocarpus longan Lour.</i> (Longan)	Barks	Solvent extraction: 70% acetone/H ₂ O were first ultrasonic extracted the powder of longan bark and then further purified by petroleum ether (PE) and ethyl acetate to obtain the condensed tannins (CTs) of longan	Antityrosinase: Monophenolase and diphenolase activity assay and intracellular tyrosinase	CTs: 43.7 ± 0.3 μg/mL		44	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Erica arborea</i> L.	Leaves	bark with concentrations of 50, 100, 150, 200 $\mu\text{g/mL}$	activity assay using B16 mouse melanoma cells	NR	-Diphenolase IC_{50} : CTs: $11.5 \pm 0.8 \mu\text{g/mL}$ -In intracellular tyrosinase activity assay, 200 $\mu\text{g/mL}$ of condensed tannins significantly reduced intracellular tyrosinase activity of B16 cells to $40.3 \pm 1.5\%$. -Kojic acid as positive control	Antioxidant:	45
		Solvent extraction: EtOH	Antityrosinase: Mushroom tyrosinase activity assay				
		Temperature: 120 $^{\circ}\text{C}$	Antioxidant: DPPH, ABTS, FRAP, and CUPRAC assays, metal chelating, PM methods				
		Extraction method: Accelerated solvent extraction (ASE), microwave-assisted extraction (MAE), maceration (MAC), Soxhlet (SOE), and ultrasound-assisted extraction (UAE)	Enzyme inhibition activity: Cholinesterase, α -amylase and α -glucosidase inhibition assays				
					MAE: 180.29 ± 1.87 MAC: 171.18 ± 3.45 SOE: 172.20 ± 1.82 UAE: 171.05 ± 1.14	a) DPPH assay (mg TE/g extract): ASE: 209.59 ± 4.37	
					MAE: 179.17 ± 2.93 MAC: 92.19 ± 1.46 SOE: 76.43 ± 0.90 UAE: 66.61 ± 3.41	b) ABTS assay (mg TE/g extract): ASE: 359.45 ± 18.22 MAE: 325.87 ± 9.48 MAC: 176.27 ± 9.25 SOE: 185.15 ± 6.28 UAE: 148.06 ± 1.96	
						c) CUPRAC assay (mg TE/g extract): ASE: 872.24 ± 9.87	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						MAE: 782.27 ± 10.12 MAC: 449.96 ± 11.72 SOE: 442.15 ± 7.75 UAE: 340.90 ± 6.89	
						d) FRAP assay (mg TE/g extract): ASE: 590.53 ± 4.19 MAE: 532.11 ± 9.52 MAC: 328.78 ± 8.42 SOE: 324.48 ± 5.74 UAE: 227.36 ± 1.44	
						e) Metal chelating assay (mg EDTAE/g extract): ASE: 4.74 ± 0.30 MAE: 3.49 ± 0.40 MAC: 3.80 ± 0.16 SOE: 1.43 ± 0.01 UAE: 5.13 ± 0.42	
						f) PM method (mmol TE/g extract): ASE: 1.84 ± 0.03 MAE: 1.66 ± 0.04 MAC: 1.50 ± 0.05 SOE: 1.66 ± 0.05 UAE: 1.26 ± 0.03	
						Cholinesterase inhibition (mg GALAE/g extract): AChE inhibition: ASE: 3.71 ± 0.03 MAE: 4.33 ± 0.03 MAC: 4.91 ± 0.14 SOE: 4.67 ± 0.18 UAE: 4.91 ± 0.11 BChE inhibition: ASE: 5.52 ± 0.05 MAE: 5.69 ± 0.06 MAC: 5.99 ± 0.06	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Fagus sylvatica</i> L.	Bark	Extraction method: Microwave-assisted extraction Solvent extraction: H ₂ O, 50:50 EtOH-H ₂ O, 80:20 EtOH-H ₂ O	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate Antioxidant: DPPH and FRAP assays Antidiabetic: α -glucosidase inhibitory assay	NR	-Kojic acid as positive control	SOE: 5.97 $\pm$ 0.13 UAE: 6.18 $\pm$ 0.01 α -amylase inhibition (mmol ACAE/g extract): ASE: 0.52 $\pm$ 0.04 MAE: 0.39 $\pm$ 0.02 MAC: 0.48 $\pm$ 0.06 SOE: 0.38 $\pm$ 0.03 UAE: 0.39 $\pm$ 0.06 α -glucosidase inhibition (mmol ACAE/g extract): ASE: 1.63 $\pm$ 0.02 MAE: 1.64 $\pm$ 0.01 MAC: 1.60 $\pm$ 0.01 SOE: 1.57 $\pm$ 0.01 UAE: 1.62 $\pm$ 0.01 Antioxidant: a) DPPH assay (mg TE/g extract): H ₂ O: 676.29 $\pm$ 19.80 50:50 EtOH/H ₂ O: 741.43 $\pm$ 59.44 80:20 EtOH/H ₂ O: 505.02 $\pm$ 42.02 b) FRAP assay (mg TE/g extract): H ₂ O: 625.13 $\pm$ 9.62 50:50 EtOH/H ₂ O: 783.24 $\pm$ 31.24 80:20 EtOH/H ₂ O: 592.84 $\pm$ 44.02 Antidiabetic activity: -Acarbose as positive control -IC ₅₀ (μ g/mL): H ₂ O: 92	46

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Feijoa sellowiana</i>	Leaves	Solvent extraction: Methylene chloride	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate Antioxidant: DPPH, ABTS, FRAP, CUPRAC, PM and metal chelating assays Enzyme inhibition activity: α -glucosidase, α -amylase, and cholinesterase inhibition assays	NR	-Kojic acid, quercetin as positive control -Tyrosinase inhibition (mg KAE/g extract): Extract: 115.85 $\pm$ 2.55	50:50 EtOH/H ₂ O: 168	47
						80:20 EtOH/H ₂ O: 38	
						Acarbose: 838	
						Antioxidant: a) DPPH assay (mg TE/g extract):	
						Extract: 90.58 $\pm$ 0.89	
						b) ABTS assay (mg TE/g extract): -Trolox as standard	
						Extract: 113.80 $\pm$ 0.02	
						c) FRAP assay (mg TE/g extract): -Trolox as standard	
						Extract: 102.58 $\pm$ 0.41	
						d) CUPRAC assay (mg TE/g extract): -Trolox as standard	
						Extract: 180.23 $\pm$ 0.44	
						e) Metal chelating assay (mg EDTAE/g extract): -EDTA as standard	
						Extract: 21.21 $\pm$ 0.88	
						f) PM assay (mg TE/g extract): -Trolox as standard	
						Extract: 5.31 $\pm$ 0.13	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Galla rhois</i>	NR	Solvent extraction: MeOH	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	NR	-Kojic acid, ascorbic acid, arbutin as positive controls	Cholinesterase inhibition (mg GALAE/g extract): -Galantamine as positive control AChE inhibition: -Extract: 4.18 ± 0.37 BChE inhibition: -Extract: 2.55 ± 0.16 α -glucosidase inhibition (mmol ACAE/g extract): -Acarbose as positive control -Extract: 1.52 ± 0.01 α -amylase inhibition (mmol ACAE/g extract): -Acarbose as positive control -Extract: 1.06 ± 0.01 NR	48
<i>Garcinia atroviridis</i> Griff. ex. T. Anderson	Fruit pericarps	Solvent extraction: H ₂ O with concentrations of 7.81, 15.63, 31.25, 62.50, 125, 250, 500, 1000 μ g/mL Temperature: 105 °C	Antimelanogenesis: Melanin content assay using B16F10 mouse melanoma cells Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate and cellular tyrosinase activity in B16F10 cells	-Kojic acid as positive control	-Tyrosinase inhibition IC ₅₀ (mg/mL): MeOH: 0.163 Kojic acid: 0.316 Ascorbic acid: 1.520 Arbutin: 2.511 Mushroom tyrosinase activity:	Antioxidant:	49
				-Kojic acid and 125 μ g/mL of H ₂ O extract reduced the melanin content to 46.94% and 46.96%, respectively in α -MSH-stimulated B16F10 cells	-Kojic acid as positive control	a) DPPH assay:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Gentiana vetchiorum</i>	Flowers, roots	Solvent extraction: Milli-Qwater Temperature: 80 °C	Antioxidant: DPPH and ABTS assays	Antimelanogenesis	- IC ₅₀ :	-Ascorbic acid as standard	50
					H ₂ O extract: 40.72 ± 1.83 μg/mL	-IC ₅₀ :	
					Kojic acid: 8.00 ± 0.47 μg/mL	H ₂ O extract: 628.85 ± 32.67 μg/mL	
					Cellular tyrosinase activity: -Only concentration of 125 μg/mL of H ₂ O extract effectively inhibited the cellular tyrosinase activity in B16F10 cells.	Ascorbic acid: 62.22 ± 0.67 μg/mL b) ABTS assay:	
						-Ascorbic acid as standard -IC ₅₀ : H ₂ O extract: 321.41 ± 12.76 μg/mL Ascorbic acid: 6.27 ± 0.19 μg/mL Antioxidant: The flower extracts and isoorientin significantly reduced the cellular ROS level	
Granny Smith apple	Fruits	Preparation: Cells of Granny Smith apple were obtained and powdered. The dried cell powder was extracted	Antimelanogenesis: Melanin content assay using B16F10 murine melanoma cells	Antimelanogenesis	Antityrosinase	Others	51
Granny Smith apple	Fruits	Preparation: Cells of Granny Smith apple were obtained and powdered. The dried cell powder was extracted	Antityrosinase: Mushroom tyrosinase activity assay	Antimelanogenesis	Antityrosinase	Others	NR

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Hippophae rhamnoides</i> L.	Seed residues	with MeOH and 1% Butylated hydroxytoluene at 25 °C	using L-DOPA as a substrate		-Tyrosinase inhibition IC ₅₀ (mg/mL): Granny Smith culture cell extract: 1.21		12
					Kojic acid: 0.0177		
				-Kojic acid as positive control	-Kojic acid as positive control	Antioxidant:	
				Antimelanogenesis: Melanin content assay using B16F10 mouse melanoma cells		a) DPPH assay: The seed residues extract (concentration ranged from 0.10 mg mL ⁻¹ to 3.00 mg mL ⁻¹) significantly reduced the tyrosinase activity in B16F10 cells, compared to the control	
<i>Juglans mandshurica</i>	Dried fruits	Solvent extraction: 80% EtOH	Antityrosinase: DPPH assay, hydroxyl radical scavenging assay			-Ascorbic acid and trolox as standards	52
						-EC ₅₀ (mg mL ⁻¹): Seed residues extract: 0.09 ± 0.01 Ascorbic acid: 0.25 ± 0.02 Trolox: 0.10 ± 0.00	
						b) Hydroxyl radical scavenging assay	
				-The seed residues extract showed little hydroxyl scavenging ability		NR	
<i>Juglans mandshurica</i>	Dried fruits	Solvent extraction: MeOH	Antimelanogenesis: Melanin content assay using B16F10, a melanoma cell line	-Fruit MeOH extract showed antimelanogenesis effects in B16F10 melanoma cells by significantly reduced expression of MITF	-Kojic acid as positive control		52
				-Compound 1 showed the strongest antimelanogenesis			
<i>Juglans mandshurica</i>	Dried fruits	Extracted crude extract subsequently partitioned into: chloroform, EtOAc, H ₂ O (3 fractions)	Antityrosinase: Tyrosinase activity assay				52

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Kadsura coccinea</i>	Roots, stems, leaves, fruits	Fractions were further isolated to obtain 3 phenolic compounds which are 2-[4-(3-hydroxypropyl)-2-methoxyphenoxy]-1,3-propanediol (1), (–)-evofolin B (2) and (2S)-schweinfurthol (3) Solvent extraction: ethyl alcohol	using L-DOPA as a substrate	sis effects by effectively decreasing expression of MITF and decreasing melanin contents in a dose-dependent manner	decreasing tyrosinase expression		53
				-Arbutin as positive control	-Arbutin as positive control	Antioxidant:	
				-Leaves > roots > stems > fruits (highest to lowest)	-Leaves > roots > stems > fruits (highest to lowest)	a) DPPH assay:	
						DPPH radical scavenging activity (%) : Leaves (99.9 ± 0.1%) >Roots (95.5 ± 3.6%) > Seeds (25.7 ± 2.1%) > Flowers (8.7 ± 1.1%) (highest to lowest) b) ABTS assay: ABTS radical scavenging activity (%) : Leaves (94.7 ± 2.9%) > Roots (82.8 ± 5.9%) > Seeds (29.7 ± 2.0%) > Flowers (15.9 ± 2.0%) (highest to lowest) Antioxidant:	
<i>Kummerowia striata</i>	Aerial parts	Solvent extraction: EtOH	Antimelanogenesis: Melanin content assay using B16F10,	-Arbutin as positive control	-Arbutin as positive control		54

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Leonurus japonicus</i>		Extracted crude extract partitioned into: CH ₂ Cl ₂ , EtOAc, <i>n</i> -BuOH	a melanoma cell line Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate	-EtOH extract decreased the melanin content in α -MSH-stimulated B16F10 cells in a dose-dependent manner	-EtOH extract exerted a significant mushroom tyrosinase inhibitory activity in a dose-dependent manner	a) DPPH assay:	
		Temperature: 25 °C	Antioxidant: DPPH and ABTS assays			-BHA as standard -IC ₅₀ (μ g/mL): EtOH extract: 98.71 BHA: 14.96 b) ABTS assay: -BHA as standard -IC ₅₀ (μ g/mL): EtOH extract: 24.64 μ g/mL BHA: 4.65	
	Aerial parts	Solvent extraction: MeOH	Antimelanogenesis: Melanin content assay using B16F10 murine melanoma cells	Five diterpenes identified from the extracts could inhibit melanin production in α -MSH-stimulated B16F10 cells	Two diterpenes from the extracts had moderate antityrosinase activity	NR	55
		Extracted crude extract fractionated into: EtOAc, H ₂ O, hexane, 95% MeOH	Antityrosinase: Cellular tyrosinase activity assay in B16F10 cells				
		Fractions were further used to isolate 25 bioactive compounds Temperature: 25 °C Solvent extraction: 96% EtOH					
<i>Lepedchinia meyerii</i>	NR		Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine and L-DOPA as substrates	NR	-Kojic acid as positive control	NR	56

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Limonium delicatulum</i>	Leaves, roots	Extracted crude extract was first fractioned and three compounds were further isolated which were p-coumaric acid, caffeic acid, and rosmarinic acid	Antityrosinase: Tyrosinase inhibition assay using L-DOPA as a substrate Antioxidant: DPPH, ABTS, CUPRAC assays, galvinoxyl radical (GOR) scavenging activity, reducing power, Phenanthroline assay, sliver nanoparticle assay (SNP), β-carotene-linoleic acid bleaching assay Anti-inflammatory: Determined <i>in vitro</i> by the thermal denaturation of bovine serum albumin (BSA)	Antimelanogenesis	-Tyrosinase inhibition IC_{50} using L-tyrosine (μM):		57
					p-coumaric acid: 0.30		
					Caffeic acid: 1.50		
					Rosmarinic acid: 4.14		
					Kojic acid: 33.45		
					-Tyrosinase inhibition IC_{50} using L-DOPA (μM):		
					p-coumaric acid: 0.62		
					Caffeic acid: 2.30		
					Rosmarinic acid: 8.59		
					Kojic acid: 38.98		
				NR	-Kojic acid as positive control	Antioxidant:	
		Solvent extraction: MeOH, H ₂ O				a) DPPH assay:	
		Temperature: 25 °C			-Tyrosinase inhibition IC_{50} ($\mu g/mL$):		
					MeOH leaves: 24.77 $\pm$ 0.5	- IC_{50} ($\mu g/mL$):	
						MeOH leaves: 10.58 $\pm$ 0.18	
					MeOH roots: 9.87 $\pm$ 0.15	MeOH roots: 5.79 $\pm$ 0.05	
					H ₂ O-leaves: na	H ₂ O roots: 79.65 $\pm$ 0.23	
					H ₂ O roots: na		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
					Kojic acid: 25.23 ± 0.21	H ₂ O roots: 69.34 ± 0.95 BHA: 6.68 ± 0.59 BHT: 16.02 ± 0.35 Ascorbic acid: 4.15 ± 0.03 Trolox: 5.25 ± 0.21	
						b) ABTS assay: -IC ₅₀ ($\mu\text{g/mL}$): MeOH leaves: 6.56 ± 0.25 MeOH roots: 7.29 ± 0.04 H ₂ O leaves: 26.01 ± 0.93 H ₂ O roots: 29.16 ± 0.16 BHA: 1.55 ± 0.26 BHT: 7.54 ± 0.69 Ascorbic acid: 3.21 ± 0.06 Trolox: 3.04 ± 0.05	
						c) GOR: -IC ₅₀ ($\mu\text{g/mL}$): MeOH leaves: 11.09 ± 0.16 MeOH roots: 10.31 ± 0.82 H ₂ O leaves: 84.07 ± 0.44 H ₂ O roots: 50.17 ± 2.09 BHA: 3.32 ± 0.18 BHT: 5.38 ± 0.06 Ascorbic acid: 5.02 ± 0.01 Trolox: 4.31 ± 0.05	
						d) CUPRAC assay: -A _{0.5} ($\mu\text{g/mL}$): MeOH leaves: 13.5 ± 0.55 MeOH roots: 6.81 ± 0.07 H ₂ O leaves: 171.94 ± 0.83 H ₂ O roots: 80.16 ± 1.36 BHA: 4.81 ± 0.87 BHT: 1.82 ± 0.19 Ascorbic acid: 8.69 ± 0.14	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						Trolox: 8.31 ± 0.15	
						e) Reducing power:	
						-A _{0.5} ($\mu\text{g/mL}$):	
						MeOH leaves: 11.2 ± 0.06	
						MeOH roots: 20.51 ± 0.3	
						H ₂ O leaves: 95.57 ± 2.02	
						H ₂ O roots: 46.54 ± 0.4	
						BHA: 9.29 ± 0.22	
						BHT: 8.41 ± 1.46	
						Ascorbic acid: 5.45 ± 0.15	
						Trolox: 3.62 ± 0.29	
						f) Phenanthroline assay:	
						-A _{0.5} ($\mu\text{g/mL}$):	
						MeOH leaves: 7.34 ± 0.27	
						MeOH roots: 3.55 ± 0.02	
						H ₂ O leaves: 22.6 ± 1.36	
						H ₂ O roots: 11.82 ± 0.75	
						BHA: 2.24 ± 0.17	
						BHT: 0.93 ± 0.07	
						Ascorbic acid: 5.25 ± 0.20	
						Trolox: 3.11 ± 0.09	
						g) SNP:	
						-A _{0.5} ($\mu\text{g/mL}$):	
						MeOH leaves: 9.45 ± 0.9	
						MeOH roots: 21.66 ± 0.08	
						H ₂ O leaves: 46.60 ± 0.46	
						H ₂ O roots: 96.24 ± 1.70	
						Ascorbic acid: 7.14 ± 0.05	
						Trolox: 34.17 ± 1.23	
						h) β-Carotene-linoleic acid bleaching assay:	
						-IC ₅₀ ($\mu\text{g/mL}$):	
						MeOH leaves: 98.6 ± 0.32	
						MeOH roots: >50	
						H ₂ O leaves: 293.17 ± 0.14	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Lophira lanceolata</i> Tiegh. ex Keay	Stem barks, leaves	Extraction method: Infusion, Soxhlet (SOX), maceration (MAC), homogenizer-assisted extraction (HAE) technique Solvent extraction: MeOH, H ₂ O	Antityrosinase: Colorimetric enzyme inhibition assay Antioxidant: DPPH, ABTS, CUPRAC, FRAP, and ferrous-ion chelating assays α-glucosidase, α-amylase, and cholinesterase inhibition: Colorimetric enzyme inhibition assays	NR	-Kojic acid as positive control -Tyrosinase inhibition (mg KAE/g):	H ₂ O roots: >50 BHA: 1.24 $\pm$ 0.01 BHT: 1.26 $\pm$ 0.03 Anti-inflammatory: -Diclofenac sodium as standard -Inhibition (%) at 500 μ g/mL: MeOH leaves: 90.21 $\pm$ 1.69 MeOH roots: 89.74 $\pm$ 1.63 H ₂ O leaves: 43.32 $\pm$ 0.13 H ₂ O roots: 38.14 $\pm$ 0.81 Antioxidant:	58
						A) DPPC assay (mgTE/g extract): Leaves: HAE-MeOH: 126.03 $\pm$ 3.57 HAE- H ₂ O: na MAC-MeOH: 122.21 $\pm$ 2.79 MAC-H ₂ O: na Soxhlet: 131.17 $\pm$ 1.96 Infusion: 4.65 $\pm$ 0.19 Stem barks: HAE-MeOH: 151.65 $\pm$ 0.25 HAE-H ₂ O: 94.58 $\pm$ 1.87 MAC-MeOH: 153.21 $\pm$ 0.15 MAC-H ₂ O: 100.46 $\pm$ 2.27 HAE-MeOH: 93.82 $\pm$ 0.23 HAE- H ₂ O: 74.38 $\pm$ 1.49 MAC-MeOH: 85.82 $\pm$ 0.15 MAC-H ₂ O: 76.44 $\pm$ 0.71 Soxhlet: 93.37 $\pm$ 0.18 Infusion: 93.81 $\pm$ 0.43 Stem barks: HAE-MeOH: 194.83 $\pm$ 0.21 HAE-H ₂ O: 190.53 $\pm$ 0.24 MAC-MeOH: 195.23 $\pm$ 0.24 MAC-H ₂ O: 189.07 $\pm$ 0.48	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
					Soxhlet: 151.98 ± 0.66 Infusion: 100.95 ± 2.37	Soxhlet: 195.18 ± 0.55 Infusion: 187.70 ± 0.47 b) ABTS assay (mgTE/g extract): Leaves: HAE-MeOH: 132.25 ± 0.09 HAE-H ₂ O: 72.57 ± 0.09 MAC-MeOH: 129.28 ± 0.19 MAC-H ₂ O: 73.35 ± 1.25 Soxhlet: 132.09 ± 0.07 Infusion: 129.90 ± 1.13 Stem barks: HAE-MeOH: 264.43 ± 0.13 HAE-H ₂ O: 263.35 ± 0.53 MAC-MeOH: 263.93 ± 0.07 MAC-H ₂ O: 263.90 ± 0.39 Soxhlet: 265.04 ± 0.99 Infusion: 261.52 ± 3.99 c) CUPRAC assay (mgTE/g extract): Leaves: HAE-MeOH: 287.73 ± 21.98 HAE-H ₂ O: 123.07 ± 1.57 MAC-MeOH: 239.54 ± 0.86 MAC-H ₂ O: 123.09 ± 0.46 Soxhlet: 284.72 ± 5.61 Infusion: 257.11 ± 0.16 Stem barks: HAE-MeOH: 794.11 ± 13.71 HAE-H ₂ O: 849.09 ± 2.23 MAC-MeOH: 735.75 ± 16.98 MAC-H ₂ O: 853.99 ± 13.27 Soxhlet: 709.05 ± 1 1.31 Infusion: 581.83 ± 6.02 d) FRAP assay (mgTE/g extract): Leaves:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						HAE-MeOH: 231.21 ± 0.57	
						HAE-H ₂ O: 97.97 ± 0.73	
						MAC-MeOH: 174.22 ± 2.71	
						MAC-H ₂ O: 106.90 ± 0.87	
						Soxhlet: 212.95 ± 2.25	
						Infusion: 213.92 ± 1.68	
						Stem barks:	
						HAE-MeOH: 569.02 ± 5.23	
						HAE-H ₂ O: 648.34 ± 3.86	
						MAC-MeOH: 501.74 ± 7.13	
						MAC-H ₂ O: 683.57 ± 11.09	
						Soxhlet: 515.99 ± 25.34	
						Infusion: 354.37 ± 3.87	
						e) PM assay (mmol TE/g extract):	
						Leaves:	
						HAE-MeOH: 2.58 ± 0.35	
						HAE-H ₂ O: 1.17 ± 0.05	
						MAC-MeOH: 2.43 ± 0.21	
						MAC-H ₂ O: 1.01 ± 0.09	
						Soxhlet: 2.05 ± 0.12	
						Infusion: 1.72 ± 0.05	
						Stem barks:	
						HAE-MeOH: 4.84 ± 0.08	
						HAE-H ₂ O: 4.79 ± 0.08	
						MAC-MeOH: 4.38 ± 0.13	
						MAC-H ₂ O: 4.41 ± 0.04	
						Soxhlet: 4.37 ± 0.27	
						Infusion: 3.47 ± 0.05	
						f) Chelating assays (mg EDTAE/g extract):	
						Leaves:	
						HAE-MeOH: 22.68 ± 0.74	
						HAE-H ₂ O: 6.76 ± 1.76	
						MAC-MeOH: 30.26 ± 0.57	
						MAC-H ₂ O: 7.13 ± 1.57	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						Soxhlet: 20.76 ± 0.81	
						Infusion: 8.35 ± 0.48	
						Stem barks:	
						HAE-MeOH: 2.42 ± 0.47	
						HAE-H ₂ O: 6.15 ± 1.12	
						MAC-MeOH: 2.09 ± 0.45	
						MAC-H ₂ O: 4.35 ± 0.14	
						Soxhlet: 3.38 ± 0.81	
						Infusion: 4.92 ± 0.53	
						Cholinesterase inhibition (mg GALAE/g):	
						AChE inhibition:	
						Leaves:	
						HAE-MeOH: 4.40 ± 0.10	
						HAE- H ₂ O:	
						MAC-MeOH: 4.01 ± 0.30	
						MAC-H ₂ O: 0.51 ± 0.04	
						Soxhlet: 4.22 ± 0.21	
						Infusion: 0.24 ± 0.01	
						Stem barks:	
						HAE-MeOH: 5.18 ± 0.03	
						HAE- H ₂ O: 3.44 ± 0.08	
						MAC-MeOH: 5.11 ± 0.04	
						MAC-H ₂ O: 2.97 ± 0.09	
						Soxhlet: 5.11 ± 0.03	
						Infusion: 1.93 ± 0.19	
						BChE inhibition:	
						Leaves:	
						HAE-MeOH: na	
						HAE-H ₂ O: na	
						MAC-MeOH: na	
						MAC-H ₂ O: na	
						Soxhlet: na	
						Infusion: na	
						Stem barks:	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						HAE-MeOH: 7.87 ± 1.68	
						HAE-H ₂ O: na	
						MAC-MeOH: 7.31 ± 1.33	
						MAC-H ₂ O: na	
						Soxhlet: 8.66 ± 1.75	
						Infusion: na	
						α-glucosidase inhibition (mmol ACAE/g):	
						Leaves:	
						HAE-MeOH: 2.86 ± 0.16	
						HAE-H ₂ O:	
						MAC-MeOH: 2.74 ± 0.01	
						MAC-H ₂ O:	
						Soxhlet: 2.77 ± 0.01	
						Infusion:	
						Stem barks:	
						HAE-MeOH: $2.74 \pm 0.01a$	
						HAE-H ₂ O:	
						MAC-MeOH: 2.76 ± 0.01	
						MAC-H ₂ O:	
						Soxhlet: 2.75 ± 0.01	
						Infusion:	
						α-amylase inhibition (mmol ACAE/g):	
						Leaves:	
						HAE-MeOH: 0.60 ± 0.02	
						HAE-H ₂ O: 0.18 ± 0.01	
						MAC-MeOH: 0.66 ± 0.01	
						MAC-H ₂ O: 0.13 ± 0.01	
						Soxhlet: 0.61 ± 0.01	
						Infusion: 0.11 ± 0.01	
						Stem barks:	
						HAE-MeOH: 1.12 ± 0.02	
						HAE-H ₂ O: 0.78 ± 0.08	
						MAC-MeOH: 1.13 ± 0.02	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
Lotus	Seedpod	Solvent extraction: Hot H ₂ O (95 °C) with concentrations of 0, 5, 10, 15, 20 μ g/mL	Antimelanogenesis: Melanin content assay using B16F10 melanoma cells	10, 15, and 20 μ g/mL of the seedpod extract of lotus greatly reduced the melanin production in α -MSH-stimulated B16F10 cells	10, 15, and 20 μ g/mL of the seedpod extract of lotus significantly decreased the 65%, 76%, and 112% of tyrosinase activity in α -MSH-stimulated B16F10 cells	MAC-H ₂ O: 0.65 ± 0.03 Soxhlet: 1.13 ± 0.03 Infusion: 0.33 ± 0.03 NR	59
			Antityrosinase: Cellular tyrosinase activity assay in B16F10 cells				
Maclura tricuspidata	Leaves	Solvent extraction: MeOH	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate	NR	Two identified flavonols named kaempferol and quercetin had the most potent activity for tyrosinase inhibition	Antioxidant: Kaempferol and quercetin had good antioxidant activity	60
		Extracted crude extract partitioned into: <i>n</i> -hexane, EtOAc, <i>n</i> -BuOH, CH ₂ Cl ₂ EtOAc and CH ₂ Cl ₂ fractions were chromatographed over silica gel to give 21 active compounds.	Antioxidant: DPPH assay				
Manilkara kauki	Fruits, leaves, seeds, stem barks, woods	Solvent extraction: MeOH, H ₂ O	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate	NR	-Kojic acid and α -arbutin as positive controls	Antioxidant:	15
		Temperature: 25 °C, 60 °C	Antioxidant: DPPH and FRAP assays				
					-Tyrosinase inhibition IC ₅₀ (mg mL ⁻¹): MeOH extracts: Fruits: 0.63 ± 0.01 Leaves: 0.38 ± 0.01 Seeds: 5.56 ± 0.03 Stem barks: 0.25 ± 0.03 Woods: No activity	a) DPPH assay: DPPH radical scavenging activity (%): MeOH extracts: Fruits: 8.80 ± 0.16 Leaves: 47.01 ± 0.14 Seeds: 2.21 ± 0.05 Stem barks: 57.87 ± 0.27	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Melaleuca quinquenervia</i>	NR	Preparation: Steam-distilled essential oil was purchased with concentrations of 0, 5, 10, 20 $\mu\text{g/mL}$	Antimelanogenesis: Melanin content assay using B16 murine melanoma cells Antityrosinase: Cellular tyrosinase activity assay in B16 cells	-Arbutin as positive control	-Arbutin as positive control	Woods: 43.51 ± 0.27 H ₂ O extracts: Fruits: 0.86 ± 0.03 Leaves: 0.50 ± 0.01 Seeds: 6.73 ± 0.03 Stem barks: 0.41 ± 0.01 Woods: No activity b) FRAP assay: FRAP activity (mg TE g^{-1} crude extract): MeOH extracts: Fruits: 11.96 ± 0.64 Leaves: 209.74 ± 1.28 Seeds: 16.41 ± 0.85 Stem barks: 211.59 ± 1.40 Woods: 72.70 ± 0.85 H ₂ O extracts: Fruits: 5.48 ± 0.32 Leaves: 219.37 ± 0.32 Seeds: 4.19 ± 0.32 Stem barks: 107.33 ± 0.96 Woods: 41.59 ± 0.85 NR	1
<i>Melastoma normale</i>	Roots	Solvent extraction: 80% acetone	Antityrosinase: Mushroom tyrosinase activity assay	NR	-Kojic acid as positive control	NR	61

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Morus alba</i> L.	Dried leaves	Extracted crude extract partitioned into: PE, EtOAc. The EtOAc fraction was further divided into ten fractions. Fractions were further separated to obtain 12 compounds	Biology assays using L-DOPA as a substrate		-Quercetin, one of the compounds that was isolated, showed a significant antityrosinase activity with IC ₅₀ of 76.83 ± 2.02 μM -Kojic acid has an IC ₅₀ of 100.52 ± 2.63.		5
				Antimelanogenesis: Melanin content assay using B16F10, mouse skin melanoma cells	-Arbutin as positive control	NR	
			Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate and intracellular tyrosinase activity assay in B16F10 cells	-Three compounds isolated from EtOH extracts named, norartocarpetin, moracin J and steppogenin decreased melanin production which exhibit antityrosinase effects in α-MSH-stimulated B16F10 cells.			
<i>Morus alba</i> L.	Leaves obtained from Chiang Mai (CM), Sakon Nakhon (SK), Buriram (BR), Thailand	Fractions were further isolated to obtain 12 compounds. Temperature: 25 °C Extraction method: Maceration method, pulsed electric field (PEF) extraction method	Antityrosinase: Tyrosinase inhibitory assay that used L-tyrosine and L-DOPA as substrates	NR	-Kojic acid as positive control	Antioxidant:	62
<i>Morus alba</i> L.		Solvent extraction: 95% EtOH	Antioxidant: DPPH, ABTS and FRAP assays		-PEF extracts exhibited significant inhibitory	-Ascorbic acid as positive control	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Myrica rubra</i>	Fruits	Solvent extraction: Pure H ₂ O, 50% H ₂ O, 50% ethyl alcohol, 5% pure H ₂ O, 95% ethyl alcohol with concentrations of 0.5, 1, 1.5, 2.0 g L ⁻¹	Antimelanogenesis: Melanin quantification assay using A2058, human melanoma cells and B16F10, mouse melanoma cells	-Arbutin as positive control	effects compared to the maceration method		6
					-PEF extract from BR demonstrated the highest antityrosinase activity, with IC ₅₀ of against L-tyrosine and L-DOPA of 54.1 ± 5.4 and 32.2 ± 3.4 µg/mL, respectively	-Extracts obtained by the PEF method had higher radical scavenging activity than the maceration method.	
					-Leaves from BR had a significantly high FRAP value which is comparable to kojic acid (IC ₅₀ : 28.0 ± 5.1 µg/mL with L-DOPA as substrate)	-PEF extract from BR had DPPH inhibition of 45.3 ± 0.8%, TEAC value of 115.1 ± 2.8 mg Trolox/g extract (ABTS assay), and EC ₁ value of 52.4 ± 0.5 mg FeSO ₄ /g extract (FRAB assay).	
					-Pure H ₂ O extract has stronger inhibitory effects than 50% ethyl alcohol and 95% ethyl alcohol extracts	NR	
					Mushroom tyrosinase activity assay:		
				-2.0 g L ⁻¹ of pure H ₂ O extract reduced the melanin content to 76.5% and 82.5% in A2058 and B16F10 cells, respectively			
					-Pure H ₂ O extract has stronger inhibitory effects than 50% ethyl alcohol and 95% ethyl alcohol extracts		
					Cellular tyrosinase activity assay:		
					-2.0 g L ⁻¹ of pure H ₂ O extract reduced the cellular tyrosinase activity to 65.78% and 74.9% in A2058 and B16F10 cells, respectively		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Nardostachys jatamansi</i>	Leaves, rootstock	Preparation: <i>in vitro</i> -raised plants and wild plants were collected	Antityrosinase: Modified dopachrome method using L-DOPA as a substrate	NR	-Kojic acid as positive control	Antioxidant:	63
			Antioxidant: ABTS and PM assay, lipid peroxidation (LPO) inhibition method		-MeOH rootstock extracts of <i>in vitro</i> -cultured plants have the highest antityrosinase activity which is comparable to kojic acid	a) ABTS assay:	
			Cholinesterase inhibitory activity: Cholinesterase inhibition assay		-Tyrosinase inhibition IC_{50} ($\mu\text{g/mL}$):	-Trolox as standard	
			Antihyperglycemic activity: α -amylase inhibition assay		MeOH rootstock extracts of <i>in vitro</i> -cultured plants: 168.12 ± 3.6	- IC_{50} ($\mu\text{g/mL}$):	
			Anti-inflammatory: Spectrophotometric measurement of linoleic acid oxidation by the enzyme 5-lipoxygenase (5-LOX)		Kojic acid: 54.44 ± 2.3	MeOH rootstock extracts of <i>in vitro</i> -cultured plants: 13.55 ± 0.8	
						Trolox: 7.5 ± 1.4	
						b) PM assay:	
						-MeOH rootstock extracts of <i>in vitro</i> cultured plants: $789 \pm 8.7 \mu\text{g}$ ascorbic acid equivalents/g extract	
						c) LPO inhibition method:	
						-Rutin as standard	
						- IC_{50} ($\mu\text{g/mL}$):	
						MeOH rootstock extracts of <i>in vitro</i> cultured plants: 15.24 ± 0.8	
						Rutin: 3.82 ± 0.5	
						Cholinesterase inhibition:	
						AchE Inhibition:	
						-Galanthamine as standard	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Nepeta glomerulosa</i> Boiss.	Aerial parts	Solvent extraction: Methanol (MeOH) (100 μ g/mL) Extracted crude extract subjected to subsequent extraction with solvents (100 μ g/mL): <i>n</i> -hexane, dichloromethane (CH ₂ Cl ₂), ethyl acetate (EtOAc), <i>n</i> -butanol (<i>n</i> -BuOH), water (H ₂ O) Temperature: 25 °C	Antimelanogenesis: Melanin content assay using B16F10 melanoma cells Antityrosinase: Mushroom tyrosinase activity assay and cellular tyrosinase activity assay in B16F10 cells Antioxidant: Hydrogen peroxide scavenging assay	-Kojic acid as positive control -100 μ g/mL concentration of MeOH, EtOAc, and <i>n</i> -BuOH extracts had significant inhibitory effects on melanin synthesis	-Kojic acid as positive control -Mushroom tyrosinase activity was inhibited only by 100 μ g/mL of EtOAc extract -100 μ g/mL of methanol extract significantly inhibited cellular tyrosinase activity in B16F10 cells	-IC ₅₀ (μ g/mL): MeOH rootstock extracts of <i>in vitro</i> cultured plants: 31.18 $\pm$ 2.6 MeOH rootstock extracts of wild plants: 36.46 $\pm$ 2.1 Galantamine: 0.94 $\pm$ 0.03 Antihyperglycemic activity: -Acarbose as standard -IC ₅₀ (μ g/mL): MeOH rootstock extract of <i>in vitro</i> cultured plants: 90.69 $\pm$ 2.1 Acarbose: 52.36 $\pm$ 3.1 Anti-inflammatory: -IC ₅₀ (μ g/mL): MeOH rootstock of <i>in vitro</i> cultured plants: 14.58 $\pm$ 0.9 MeOH leaf extracts of <i>in vitro</i> cultured plants: 23.54 $\pm$ 1.6 Positive control: 2.56 $\pm$ 0.4 Antioxidant: Only MeOH and <i>n</i> -BuOH extracts greatly suppressed the oxidative stress caused by hydrogen peroxide	3
<i>Olea europaea</i>	Leaves	Solvent extraction: MeOH	Antimelanogenesis: Melanin content assay using B16 melanoma cells	-Arbutin as positive control	NR	NR	64

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Pelargonium graveolens</i>	Aerial parts	Seventeen compounds were isolated from MeOH extract Solvent extraction: <i>n</i> -hexane, CH ₂ Cl ₂ , MeOH Temperature: 25 °C	Antityrosinase: Tyrosinase inhibition assay using L-DOPA as a substrate Antioxidant: DPPH assay, ABTS assay, CUPRAC assay, reducing power, iron chelation	-Three compounds named oleuropein, oleoside dimethyl ester and oleoside 11-methyl ester, presented good inhibition of melanogenesis			65
				-Melanin content (%) at 12.5, 25, 50 μ M, respectively:			
				Oleuropein: 63.8 $\pm$ 3.3, 46.4 $\pm$ 3.3, 33.9 $\pm$ 15.4			
				Oleoside dimethyl ester: 33.9 $\pm$ 4.0, 28.1 $\pm$ 0.7, 5.3 $\pm$ 3.8			
				Oleoside 11-methyl ester: 25.8 $\pm$ 8.1, 22.3 $\pm$ 14.0, 16.0 $\pm$ 10.2			
				Arbutin at 20 μ M: 91.3 $\pm$ 2.6			
				NR	-Kojic acid as positive control	Antioxidant:	
					-Tyrosinase inhibition IC ₅₀ (μ g/mL):	a) DPPH assay:	
					<i>n</i> -hexane: 37.60 $\pm$ 1.83 CH ₂ Cl ₂ : 37.63 $\pm$ 1.35 MeOH: 21.11 $\pm$ 0.38 Kojic acid: 25.23 $\pm$ 0.78	-BHT and BHA as standard -IC ₅₀ (μ g/mL): <i>n</i> -hexane: 37.60 $\pm$ 1.83 CH ₂ Cl ₂ : 116.91 $\pm$ 6.50 MeOH: 12.96 $\pm$ 0.63 BHA: 5.73 $\pm$ 0.41	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Persicaria orientalis</i>	Roots	Solvent extraction: MeOH	Antimelanogenesis: Melanin content assay using B16 mouse melanoma cells	-Arbutin as positive control	-Kojic acid as positive control	BHT: 22.32 ± 1.19 b) ABTS assay: -BHT and BHA as standard -IC ₅₀ ($\mu\text{g/mL}$): <i>n</i> -hexane: 44.46 ± 2.30 CH ₂ Cl ₂ : 10.46 ± 1.33 MeOH: 10.20 ± 0.63 BHA: 1.81 ± 0.10 BHT: 1.29 ± 0.30 c) CUPRAC assay: -BHT and BHA as standard -IC ₅₀ ($\mu\text{g/mL}$): <i>n</i> -hexane: 89.95 ± 3.00 CH ₂ Cl ₂ : 53.36 ± 0.88 MeOH: 20.29 ± 0.51 BHT: 5.35 ± 0.71 BHA: 8.97 ± 3.94 d) Reducing power: -BHA as standard -IC ₅₀ ($\mu\text{g/mL}$): <i>n</i> -hexane: 77.29 ± 0.87 CH ₂ Cl ₂ : 64.60 ± 0.15 MeOH: 43.48 ± 0.65 BHA: 9.29 ± 0.22 e) Iron chelation: -EDTA as standard -IC ₅₀ ($\mu\text{g/mL}$): <i>n</i> -hexane: 47.20 ± 2.85 CH ₂ Cl ₂ : 66.72 ± 2.96 MeOH: 31.74 ± 3.21 EDTA: 8.80 ± 0.47 NR	66

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results		
				Antimelanogenesis	Antityrosinase	Others
<i>Photinia × fraseri</i>	Leaves	Extracted crude extract subsequently partitioned into: n-hexane, EtOAc, and EtOH extracts. Then, EtOH extract was further used to isolate the nine bioactive compounds	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine and L-DOPA as substrates	-Vanicoside B isolated from EtOH extracts exhibited a significant high extracellular (71.9% and 72.0%) and intracellular (35.3 and 27.3%) melanin inhibitory activity at 50 and 25 μM _i , respectively	-Tyrosinase inhibition IC ₅₀ using L-tyrosine (μg/mL):	
				-It showed a better inhibitory activity than arbutin (58% at 730 μM)	n-hexane: >1000	
				Bioactive compounds were tested in the concentrations of 6.25, 12.5, 25, 50 μM		
		Solvent extraction: 70% acetone	Antityrosinase: Mushroom tyrosinase monophenolase and diphenolase activity assay			
					EtOAc: 80 EtOH: 22 Kojic acid: 2	
					-Tyrosinase inhibition IC ₅₀ using L-DOPA (μg/mL): n-hexane: >1000 EtOAc: 311 EtOH: 39 Kojic acid: 26	
					PAs showed better inhibition of tyrosinase diphenolase activity than monophenolase activity	NR
<i>Phyllanthus phillyreifolius</i>	Leaves, branches, stems	H ₂ O phase was then extracted to obtain a crude proanthocyanidins (PAs) extract				
		Extraction method: Soxhlet extraction, maceration extraction, and decoction	Antityrosinase:	NR	Tyrosinase inhibition (mg KAE/g extract):	Antioxidant:
		Solvent extraction: EtOAc, 70% MeOH	Tyrosinase inhibition assay Antioxidant: DPPH, ABTS, FRAP,		- Kojic acid as positive control Decoction: 66.29 ± 1.51	a) DPPH assay (mmol TE/g extract); - Trolox as standard

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
		Sample preparation and extraction methods	Biology assays CUPRAC, and PM assays, chelating effect Enzyme inhibition activity: cholinesterase, α -amylase, and α -glucosidase inhibition assays				
					EtOAc maceration: 88.93 $\pm$ 0.53	Decoction: 1.91 $\pm$ 0.13	
					EtOAc Soxhlet: 78.79 $\pm$ 1.52	EtOAc-Maceration: 2.73 $\pm$ 0.01	
					MeOH Maceration: 88.46 $\pm$ 1.35	EtOAc Soxhlet: 2.49 $\pm$ 0.04	
					MeOH Soxhlet: 87.19 $\pm$ 0.28	MeOH Maceration: 2.91 $\pm$ 0.01	
						MeOH Soxhlet: 2.85 $\pm$ 0.02	
						b) ABTS assay (mmol TE/g extract): -Trolox as standard	
						Decoction: 4.11 $\pm$ 0.02	
						EtOAc Maceration: 3.21 $\pm$ 0.17	
						EtOAc Soxhlet: 2.65 $\pm$ 0.05	
		Sample preparation and extraction methods	Biology assays CUPRAC, and PM assays, chelating effect Enzyme inhibition activity: cholinesterase, α -amylase, and α -glucosidase inhibition assays			MeOH Maceration: 4.12 $\pm$ 0.09	
						MeOH Soxhlet: 3.68 $\pm$ 0.10	
						c) CUPRAC assay (mmol TE/g extract): -Trolox as standard	
						Decoction: 4.80 $\pm$ 0.07	
						EtOAc Maceration: 4.78 $\pm$ 0.33	
						EtOAc Soxhlet: 3.75 $\pm$ 0.03	
						MeOH Maceration: 4.96 $\pm$ 0.12	
						MeOH Soxhlet: 5.04 $\pm$ 0.17	
						d) FRAP assay (mmol TE/g extract): -Trolox as standard	
						Decoction: 3.01 $\pm$ 0.12	
		Sample preparation and extraction methods	Biology assays CUPRAC, and PM assays, chelating effect Enzyme inhibition activity: cholinesterase, α -amylase, and α -glucosidase inhibition assays			EtOAc Maceration: 2.31 $\pm$ 0.11	
						EtOAc Soxhlet: 2.02 $\pm$ 0.10	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						MeOH Maceration: 2.92 ± 0.36	
						MeOH Soxhlet: 3.17 ± 0.15	
						e) Metal chelating (mmol EDTAE/g extract):	
						-EDTA as standard	
						Decoction: 22.91 ± 0.39	
						EtOAc Maceration: 17.89 ± 0.70	
						EtOAc Soxhlet: 19.02 ± 0.42	
						MeOH Maceration: 24.23 ± 0.57	
						MeOH Soxhlet: 26.30 ± 0.10	
						Cholinesterase inhibition (mg GALAE/g extract):	
						AChE Inhibition:	
						Decoction: 2.11 ± 0.04	
						EtOAc Maceration: 2.68 ± 0.01	
						EtOAc Soxhlet: 2.56 ± 0.05	
						MeOH Maceration: 2.33 ± 0.02	
						MeOH Soxhlet: 2.13 ± 0.03	
						BChE Inhibition:	
						Decoction: 1.26 ± 0.12	
						EtOAc Maceration: 2.27 ± 0.19	
						EtOAc Soxhlet: 2.06 ± 0.11	
						MeOH Maceration: 2.73 ± 0.23	
						MeOH Soxhlet: 1.20 ± 0.20	
						α-amylase inhibition (mmol ACAE/g extract):	
						Decoction: 0.19 ± 0.02	
						EtOAc Maceration: 0.63 ± 0.04	
						EtOAc Soxhlet: 0.68 ± 0.06	
						MeOH Maceration: 0.60 ± 0.04	
						MeOH Soxhlet: 0.56 ± 0.01	
						α-glucosidase inhibition (mmol ACAE/g extract):	
						Decoction: NR	
						EtOAc Maceration: NR	
						EtOAc Soxhlet: 45.07 ± 0.39	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Phyllanthus niruri</i> <i>hirsutus</i>	Bamboo stems	Solvent extraction: H ₂ O, 50% EtOH, 80% EtOH, 100% EtOH, boiling H ₂ O	Antimelanogenesis: Melanin content assay using B16F10, a melanoma cell line	-80% EtOH extracts decreased the melanin content in α -MSH-stimulated B16F10 cells in a dose-dependent manner	-Ascorbic acid as positive control	MeOH Maceration: NR	13
						MeOH Soxhlet: NR	
						Antioxidant:	
		Extracted crude extract were then partitioned with MeOH, EtOAc, <i>n</i> -hexane	Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as a substrate Antioxidant: DPPH and ABTS assays, hydroxyl radical scavenging activity method		-Tyrosinase inhibition IC ₅₀ (μ g/mL): 80% EtOH extracts: 243.7	a) DPPH assay:	
						-Ascorbic acid as positive control	
						-IC ₅₀ (μ g/mL): H ₂ O: 1064.48 $\pm$ 107.77 50% EtOH: 714.35 $\pm$ 39.54 80% EtOH: 565.63 $\pm$ 17.75 100% EtOH: 2019.67 $\pm$ 69.40 Boiling H ₂ O: 877.34 $\pm$ 63.75 Ascorbic acid: 23.02 $\pm$ 0.39	
		Temperature: 121 °C, 25 °C, 100 °C				b) ABTS assay:	
						-Ascorbic acid as positive control	
						-IC ₅₀ (μ g/mL): H ₂ O: 704.99 $\pm$ 28.53 50% EtOH: 463.81 $\pm$ 13.93 80% EtOH: 414.61 $\pm$ 35.12 100% EtOH: 669.68 $\pm$ 35.62 Boiling H ₂ O: 2258.18 $\pm$ 125.06 Ascorbic acid: 51.86 $\pm$ 0.72	
						c) Hydroxyl radical assay:	
						-Ascorbic acid as positive control	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Pistacia atlantica</i> subsp. <i>mutica</i>	Unripe fruits	Solvent extraction and preparation: MeOH and hydrodistillation to obtain the essential oil	Antimelanogenesis: Melanin content assay using B16F10, a melanoma cell line	-Kojic acid as positive control	-Kojic acid as positive control	-IC ₅₀ (μg/mL): H ₂ O: 698.68 ± 24.40 50% EtOH: 560.19 ± 21.85 80% EtOH: 509.17 ± 33.76 100% EtOH: 766.73 ± 22.23 Boiling H ₂ O: 1395.93 ± 222.72 Ascorbic acid: 90.57 ± 0.60 Antioxidant:	11
		Extracted crude extract fractionated into: MeOH, <i>n</i> -hexane, CH ₂ Cl ₂ , EtOAc, BuOH, H ₂ O	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate and cellular tyrosinase activity assay in B16F10 cells	-MeOH, CH ₂ Cl ₂ , and EtOAc extracts (0.2–200 μg/mL), <i>n</i> -hexane (2–200 μg/mL), and H ₂ O	Mushroom tyrosinase activity assay:	-All extracts except 0.2 μg/mL of CH ₂ Cl ₂ extract were able to significantly suppress the oxidative stress caused by H ₂ O ₂	
		Temperature: 25 °C	Antioxidant: Hydrogen peroxide scavenging assay using B16F10 melanoma cells	Extract (20 and 200 μg/mL) showed significant inhibitory effect on melanogenesis, but essential oil and BuOH had no significant inhibitory effect on melanogenesis	-All extracts were able to inhibit mushroom tyrosinase activity except for 1000 μg/mL of <i>n</i> -hexane extract		
<i>Pistacia lentiscus</i> L.	Leaves	Solvent extraction: MeOH extract (ME)	Antityrosinase: Mushroom	NR	-Kojic acid as positive control	Antioxidant activity:	69

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Polygonum martimum</i> L.	Aerial parts (leaves and stems)	Solvent extraction: acetone Temperature: 25 °C	tyrosinase activity assay using L-DOPA as a substrate and cellular tyrosinase activity assay in B16 cells				
			Antioxidant: DPPH and FRAP assays		Mushroom tyrosinase activity assay:	a) DPPH assay:	
			Antielastase: Elastase inhibition assay		-IC ₅₀ (μg/mL):	-Ascorbic acid as standard	
			Pressurized solvent extraction to obtain the ethyl acetate (EAE) and aqueous (AE) phases		EAE: 123	-IC ₅₀ (μg/mL):	
<i>Polygonum martimum</i> L.	Aerial parts (leaves and stems)	Solvent extraction: acetone Temperature: 25 °C			Kojic acid: 20	ME: 19.62	
					Cellular tyrosinase activity:	EAE: 18.07	
					-IC ₅₀ (μg/mL):	AE: 19.52	
					EAE: 27.85 ± 1.75	Ascorbic acid: 13.85	
					Kojic acid: 142.09 ± 2.72	b) FRAP assay (mg AEAC/g extract):	
						ME: 467.29 ± 21.77	
						EAE: 522.76 ± 22.99	
						AE: 421.91 ± 15.48	
						Antielastase:	
						-Epigallocatechin gallate as positive control	
<i>Polygonum martimum</i> L.	Aerial parts (leaves and stems)	Solvent extraction: acetone Temperature: 25 °C	Antimelanogenesis: Melanin content assay using B16 4AS melanoma cells	-Melanin inhibition IC ₅₀ :	-Arbutin as positive control	Epigallocatechin gallate: 12	70
			Antityrosinase: Mushroom tyrosinase activity assay	Acetone extract: 77.7 μg/mL	-Tyrosinase inhibition IC ₅₀ (μg/mL):	Antioxidant:	
			Antioxidant: Radical			a) Radical scavenging activity on superoxide radicals:	
					Acetone extract: 64.1	-Catechin as positive control	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results				References
				Antimelanogenesis	Antityrosinase	Others		
<i>Potentilla anserina</i> L.	Rhizomes	Solvent extraction: 70% EtOH Extracted crude extract fractionated into: PE, EtOAc, butyl alcohol, aqueous	scavenging activity on superoxide radical, ferric thiocyanate, and thiobarbituric acid tests, PM method					
			Anti-inflammatory: Nitric acid production was assessed using LPS (Lipopolysaccharide)-stimulated RAW 264. Seven macrophages	Arbutin: 137	IC ₅₀ (μg/mL):	Acetone extract: 40.4 Catechin: 61.6 b) Ferric thiocyanate and thiobarbituric acid tests: IC ₅₀ (μg/mL): Acetone extract: 784 c) Total antioxidant capacity: IC ₅₀ : Acetone extract: 647 μg/mL Anti-inflammatory: IC ₅₀ (μg/mL): Acetone extract: 22.0 Positive control: 27.6 Antioxidant:		
			Antityrosinase: Tyrosinase inhibitory assay using L-tyrosine and L-DOPA as substrates	NR	-Kojic acid as positive control			
			Antioxidant: DPPH, ABTS and FRAP assays		-Butyl alcohol fraction (IC ₅₀ = 45.22 μg/mL (L-tyrosine), IC ₅₀ = 15.47 μg/mL (L-DOPA) > EtOAc fraction > EtOH > aqueous fraction (highest to lowest)	a) DPPH assay:		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
<i>Potentilla paradoxa</i> Nutt.	Whole plant	Solvent extraction: 95% EtOH	α-glucosidase inhibition: α-glucosidase inhibitory assay Antimelanogenesis: Melanin content assay using B16F10 melanoma cells Antioxidant: DPPH, ABTS, FRAP, and CUPRAC assays	-Arbutin as positive control -Melanin content of α-MSH-stimulated B16F10 cells were suppressed dose-dependently by	-Ascorbic acid as positive control -Antityrosinase	-Ascorbic acid as positive control -Others	72
			EtOAc was subjected to a silica gel column and eluted with dichloromethane/methanol to produce 10 fractions. These fractions were then further used to isolate 30 active compounds.	-IC₅₀ (μg/mL): PE fraction: NR EtOAc fraction: 0.11 Butyl alcohol fraction: 1.16 EtOH extract: 7.27 Aqueous fraction: 16.33 b) ABTS assay: -Ascorbic acid as positive control -IC₅₀ (μg/mL): PE fraction: NR EtOAc fraction: 0.42 Butyl alcohol fraction: 4.58 EtOH extract: 25.91 Aqueous fraction: 60.71 c) FRAP assay: -Ascorbic acid as positive control -EtOAc fraction is presented with the highest FRAP value. α-glucosidase inhibition: -Acarbose as positive control -Butyl alcohol fraction had the highest inhibition of α-glucosidase with an IC₅₀ value of 14.18 μg/mL Antioxidant: a) DPPH assay:	-Ascorbic acid as positive control -Others	-Ascorbic acid as positive control -Others	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Prasiola japonica</i>	NR	Preparation: Loliolide, a monoterpene hydroxylactone from <i>P. japonica</i> was purchased	Antimelanogenesis: Melanin content assay using B16F10 mouse melanoma cells Antioxidant: ABTS assay	the 95% EtOH extract		-Ascorbic as positive control -95% EtOH extract showed DPPH radical scavenging ability in a dose-dependent manner b) ABTS assay: -Ascorbic as positive control -95% EtOH extract showed ABTS radical scavenging ability in a dose-dependent manner c) FRAP assay: -Trolox as standard -95% EtOH extract displayed a ferric reducing antioxidative capacity in a dose-dependent manner. d) CUPRAC assay: -Trolox as standard -Copper ions were reduced by 95% EtOH extract in a dose-dependent manner	73
<i>Pterocarpus marsupium</i>	Heartwood	Solvent extraction of <i>P. japonica</i> : 70% EtOH Temperature: 25 °C Solvent extraction: EtOH	Antimelanogenesis: Melanin content assay using B16 cell line Antityrosinase: Mushroom	-Loliolide remarkably reduced the melanin content and secretion in α -MSH-stimulated B16F10 cells. -Kojic acid as positive control	-Kojic acid as positive control	a) ABTS assay: -Ascorbic acid as positive control -IC ₅₀ of loliolide: 61.52 $\pm$ 2.12 μ M Antioxidant: a) DPPH assay:	74

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
Red maple (<i>Acer rubrum</i>)	Leaves	Solvent extraction: EtOH	tyrosinase activity assay using L-DOPA as a substrate	extracts presented 24%, 45%, 53%, and 69% of inhibition of melanogenesis in B16 cells, respectively	and 71% mushroom tyrosinase activity, respectively		
			Antioxidant: DPPH assay			-Ascorbic acid as standard	
						-10, 20, and 50 $\mu\text{g/mL}$ of extracts demonstrated 16%, 33%, and 73% DPPH radical-scavenging activity	
						-10, 20, and 50 $\mu\text{g/mL}$ of ascorbic acid demonstrated 15%, 31%, and 84% DPPH radical-scavenging activity	
			Antimelanogenesis: Melanin content assay using B16F10, a murine melanoma cell line	Compared to the control group, 25 and 50 μM of GA effectively reduced the melanin content in B16F10 cells to 79.1% and 56.7%, respectively.	-Kojic acid and arbutin as positive controls	Antioxidant: 50 μM of GA reduced ROS levels to 55.1% in B16F10 cells	75
			Antityrosinase: Mushroom tyrosinase activity assay using L-tyrosine as substrate		-Tyrosinase inhibition IC_{50} (μM):		
			Antioxidant: Hydrogen peroxide scavenging assay using B16F10 melanoma cells		GA: 101.4 $\pm$ 6.5		
					GB: >500 GC: >500 MF: 208.9 $\pm$ 3.1 MJ: 173.8 Kojic acid: 23.7 $\pm$ 0.9		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Rosa chinensis</i> cv. "InBian"	Flower buds	Solvent extraction: 95% EtOH, 65% EtOH, PE Temperature: 25 °C	Antityrosinase: Mushroom tyrosinase activity assay using L-DOPA as a substrate Antioxidant: DPPH assay	NR	Arbutin: 61.6 ± 2.8 - α -Arbutin as positive control	Antioxidant:	76
					-Tyrosinase inhibition (%): 95% EtOH: 66.95 ± 0.27 65% EtOH: 60.21 ± 0.09 PE: 6.27 ± 0.68 α -Arbutin: 22.15 ± 0.42	a) DPPH assay: -Trolox as standard -DPPH radical scavenger (%): 95% EtOH: 94.36 ± 0.12 65% EtOH: 94.11 ± 0 PE: 17.25 ± 1.45 Trolox: 95.12 ± 0.29	
<i>Rubus cassis</i> L.	Leaves	Solvent extraction: H ₂ O (RC1), 50% MeOH (RC2), pure MeOH (RC3) Extracted crude extract partitioned into: diethyl ether (RC4), EtOAc (RC5), <i>n</i> -BuOH (RC6) Temperature: 40 °C	Antityrosinase: Tyrosinase inhibition assay using L-DOPA as a substrate Antioxidant: DPPH, ABTS, CUPRAC (Cupric Reducing Antioxidant Capacity), FRAP (Ferric reducing ability of plasma), phosphomolybdenum (PM) and metal-chelating assays Enzyme inhibitory activity: Cholinesterase, α -amylase, and α -glucosidase inhibition assays	NR	Tyrosinase inhibition (mg KAE/g extract): RC1: 60.59 ± 0.37	Antioxidant: a) DPPH assay (mmol TE/g extract):	77
						-Trolox as standard	
					RC2: 61.82 ± 1.43		
					RC3: 61.83 ± 0.26 RC4: 55.32 ± 0.67 RC5: 56.92 ± 0.70 RC6: 63.12 ± 0.26	RC1: 0.17 ± 0.01 RC2: 0.57 ± 0.04 RC3: 1.05 ± 0.02 RC4: 1.58 ± 0.01	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results				References
			Biology assays	Antimelanogenesis	Antityrosinase	Others	
						RC5: 1.58 ± 0.01	
						RC6: 1.55 ± 0.02	
						b) ABTS assay (mmol TE/g extract):	
						-Trolox as standard	
						RC1: 0.25 ± 0.01	
						RC2: 1.22 ± 0.08	
						RC3: 1.28 ± 0.03	
						RC4: 2.45 ± 0.03	
						RC5: 2.92 ± 0.03	
						RC6: 2.02 ± 0.03	
						c) CUPRAC assay (mmol TE/g extract):	
						-Trolox as standard	
						RC1: 0.34 ± 0.01	
						RC2: 1.63 ± 0.02	
						RC3: 1.60 ± 0.05	
						RC4: 3.49 ± 0.02	
						RC5: 4.98 ± 0.05	
						RC6: 2.82 ± 0.18	
						d) FRAP assay (mmol TE/g extract):	
						-Trolox as standard	
						RC1: 0.22 ± 0.01	
						RC2: 1.05 ± 0.03	
						RC3: 0.92 ± 0.04	
						RC4: 2.15 ± 0.08	
						RC5: 2.78 ± 0.13	
						RC6: 1.71 ± 0.21	
						e) PM method (mmol TE/g extract):	
						-Trolox as standard	
					RC1: 0.59 ± 0.02		
					RC2: 1.61 ± 0.15		
					RC3: 2.09 ± 0.18		
					RC4: 2.58 ± 0.11		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Results			References	
			Biology assays	Antimelanogenesis	Antityrosinase		Others
						RC5: 3.92 ± 0.34	
						RC6: 3.10 ± 0.26	
						f) Metal chelating assays (mg EDTAE/g extract):	
						-EDTA as standard	
						RC1: 12.00 ± 0.38	
						RC2: 16.62 ± 1.71	
						RC3: 14.67 ± 1.13	
						RC4: 5.19 ± 0.20	
						RC5: 8.07 ± 0.82	
						RC6: 12.94 ± 0.87	
						Cholinesterase inhibition:	
						AChE inhibition (mg GALAE/g extract):	
						RC1: 1.99 ± 0.04	
						RC2: 2.06 ± 0.07	
						RC3: 2.26 ± 0.05	
						RC4: 2.46 ± 0.01	
						RC5: 2.17 ± 0.02	
						RC6: 2.13 ± 0.05	
						BChE inhibition (mg GALAE/g extract):	
						RC1: 1.01 ± 0.03	
						RC2: 1.00 ± 0.09	
						RC3: 1.10 ± 0.0	
						RC4: NR	
						RC5: NR	
						RC6: NR	
						α-amylase inhibition (mmol ACAE/g extract):	
					RC1: 0.39 ± 0.03		
					RC2: 0.50 ± 0.04		
					RC3: 0.60 ± 0.02		
					RC4: 0.70 ± 0.07		
					RC5: 0.59 ± 0.05		
					RC6: 0.52 ± 0.09		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results				References
				Antimelanogenesis	Antityrosinase	Others	Glucosidase inhibition (mmol ACAE/g extract):	
<i>Scabiosa columbaria</i>	Leaves	Solvent extraction: MeOH with concentrations of 25, 50, 100, 200 µg/mL	Antimelanogenesis: Melanin content assay using B16F10 melanoma cells	-Kojic acid as positive control	-Kojic acid as positive control		RC1: 1.44 ± 0.02 RC2: 1.90 ± 0.02 RC3: 1.95 ± 0.01 RC4: 1.97 ± 0.14 RC5: 2.03 ± 0.01 RC6: 1.94 ± 0.02	78
			Antityrosinase: Mushroom tyrosinase inhibition assay using L-DOPA as a substrate	-The extracts inhibited melanogenesis in α-MSH-stimulated B16F10 cells with increasing concentrations	-The extract exhibited tyrosinase inhibitory activity in a dose-dependent manner	a) FRAP assay:		
			Antioxidant: FRAP assay	-At 100 µg/mL of extracts, cellular melanin content was decreased to around 40%		-Trolox as standard		
<i>Schinus terebinthifolius</i>	Fruits, leaves	Solvent extraction: Hexane, acetone, MeOH, oil	Antioxidant: DPPH and ABTS assays	NR	-Kojic acid as positive control		-The extracts displayed a significant FRAP activity than control, especially at 200 µg/mL	79
			Antityrosinase: Tyrosinase inhibition activity assay using L-tyrosine as a substrate		-Tyrosinase inhibition of leaves extracts (%):	a) DPPH assay:		
					Hexane: 73.68 ± 1.56 Acetone: 92.10 ± 1.81 MeOH: 100 ± 0.0 -Tyrosinase inhibition of fruit extracts (%): Oil: 5.26 ± 0.6 Acetone: 78.94 ± 1.2	-Trolox as standard: -IC ₅₀ of leaf extracts (mg mL ⁻¹): Hexane: 1.84 Acetone: 0.62 MeOH: 0.53 -IC ₅₀ of fruit extracts (mg mL ⁻¹):		

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Schisandra chinensis</i> (Turcz.) Baillon	Dried fruits	Solvent extraction: 95% ethanol (EtOH)	Antimelanogenesis: Melanin content assay using B16F10, melanoma cells	-Arbutin as positive control	MeOH: 63.15 ± 1.43 Kojic acid: 86.7 ± 1.75	Oil: 0.016 Acetone: 1.02 MeOH: 0.41 Trolox: 0.136 mg mL ⁻¹ b) ABTS assay: -Trolox as standard: -IC ₅₀ of leaf extracts (mg mL ⁻¹): Hexane: 1.29 Acetone: 0.87 MeOH: 0.76 -IC ₅₀ of fruit extracts (mg mL ⁻¹): oil: 0.017 Acetone: 0.98 MeOH: 0.61 Trolox: 0.145 NR	2
	Extracted crude extract fractionated into: <i>n</i> -hexane, CH ₂ Cl ₂ , EtOAc, <i>n</i> -BuOH, H ₂ O Temperature: 25 °C		-Melanin inhibition IC ₅₀ (μg/mL): 95% EtOH: 98.37 <i>n</i> -hexane: 11.58 CH ₂ Cl ₂ : 27.89 EtOAc: >100 <i>n</i> -BuOH: >100 H ₂ O: >100 NR				
<i>Scorzonera tomentosa</i> L.	Aerial parts, roots	Solvent extraction: hexane, EtOAc, CH ₂ Cl ₂ , MeOH, H ₂ O Temperature: 25 °C	Antityrosinase: Standard <i>in vitro</i> bioassays Antioxidant: DPPH, ABTS, CUPRAC, FRAP, metal chelating, PM assay	-Kojic acid as positive control NR	-Kojic acid as positive control	Antioxidant: a) DPPH and ABTS assays: -Tyrosinase inhibition (mg KAE/g extract):	80

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays α -glucosidase, α -amylase, and cholinesterase inhibition: Standard <i>in vitro</i> bioassays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
					Aerial parts:	-MeOH and H ₂ O extracts of both plant parts showed good free radical scavenging ability	
					CH ₂ Cl ₂ : 63.32 $\pm$ 0.22	b) CUPRAC assay:	
					EtOAc: 61.65 $\pm$ 0.45	-MeOH extracts of both plant parts showed the highest activity (aerial parts: 164.06 $\pm$ 1.26 and roots: 93.18 $\pm$ 1.58 mg TE/g)	
					Hexane: 57.54 $\pm$ 0.12	c) FRAP assay:	
					H ₂ O: 16.40 $\pm$ 1.30	-MeOH extracts of roots (79.78 $\pm$ 0.27 mgTE/g) and H ₂ O extracts (41.36 $\pm$ 0.10 mg TE/g) of aerial parts were excellent sources of reducing agents	
					MeOH: 64.83 $\pm$ 0.28	d) Metal chelating assay:	
					Roots:	-H ₂ O and CH ₂ Cl ₂ extracts of aerial parts have a metal chelating activity ranged from 2.13 $\pm$ 0.10 to 13.92 $\pm$ 0.86 mg EDTAE/g	
					CH ₂ Cl ₂ : 60.28 $\pm$ 0.23	-MeOH and CH ₂ Cl ₂ extracts of roots have a metal chelating activity ranging from 0.53 $\pm$ 0.07 to 6.24 $\pm$ 0.17 mg EDTAE/g	
					EtOAc: 59.99 $\pm$ 0.19	-H ₂ O and hexane roots extracts showed no activity	
					Hexane: 63.54 $\pm$ 0.56	e) PM assay:	
					H ₂ O: 6.29 $\pm$ 0.50	-All plant parts extracts were found to have moderate activity	
					MeOH: 65.46 $\pm$ 0.31	Cholinesterase inhibition (mg GALAE/g):	
						AChE inhibition:	
						Aerial parts:	
						CH ₂ Cl ₂ : 2.57 $\pm$ 0.07	
						EtOAc: 2.15 $\pm$ 0.24	
						Hexane: 1.98 $\pm$ 0.24	
						H ₂ O: 2.13 $\pm$ 0.09	
						MeOH: 1.96 $\pm$ 0.10	
						Roots:	
						CH ₂ Cl ₂ : 2.41 $\pm$ 0.01	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						EtOAc: 2.17 ± 0.23	References
						Hexane: 2.40 ± 0.27	
						H ₂ O: 1.83 ± 0.06	
						MeOH: 1.91 ± 0.04	
						BChE inhibition:	
						Aerial parts:	
						CH ₂ Cl ₂ : na	
						EtOAc: na	
						Hexane: na	
						H ₂ O: na	
						MeOH: na	
						Roots:	
						CH ₂ Cl ₂ : 1.92 ± 0.17	
						EtOAc: 3.80 ± 0.24	
						Hexane: 3.96 ± 0.57	
						H ₂ O: na	α -glucosidase inhibition (mmol ACAE/g):
						MeOH: 4.78 ± 0.23	
						Aerial parts:	
						CH ₂ Cl ₂ : 0.65 ± 0.04	
						EtOAc: 0.70 ± 0.02	
						Hexane: 0.75 ± 0.01	
						H ₂ O: 0.18 ± 0.01	
						MeOH: 0.14 ± 0.01	
						Roots:	
						CH ₂ Cl ₂ : 0.68 ± 0.01	
						EtOAc: 0.67 ± 0.01	
						Hexane: 0.83 ± 0.01	
						H ₂ O: 0.09 ± 0.01	
						MeOH: 0.67 ± 0.07	
						α -amylase inhibition (mmol ACAE/g):	
						Aerial parts:	
						CH ₂ Cl ₂ : 0.57 ± 0.02	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Sorghum bicolor</i>	NR	Solvent extraction: 0, 20, 40, 60, 80, 95% EtOH Temperature: 40 °C	Antimelanogenesis: Melanin content assay using B16F10 melanoma cells Antityrosinase: Tyrosinase inhibitory assay using L-tyrosine and L-DOPA as substrate	-Arbutin as positive control	-Arbutin as positive control	EtOAc: 0.60 ± 0.02 Hexane: 0.46 ± 0.02 H ₂ O: 0.08 ± 0.01 MeOH: 0.40 ± 0.01 Roots: CH ₂ Cl ₂ : 0.55 ± 0.02 EtOAc: 0.57 ± 0.01 Hexane: 0.61 ± 0.02 H ₂ O: 0.09 ± 0.01 MeOH: 0.26 ± 0.05 Antioxidant:	81
						a) DPPH assay: -Tyrosinase inhibition IC ₅₀ using L-tyrosine (μg/mL):	
						60% EtOH extract: 89.25 Arbutin: 74.35	
						-Vitamin C as standard -IC ₅₀ of 60% EtOH extract: 612.53 μg/mL b) ABTS assay: -Tyrosinase inhibition IC ₅₀ using L-DOPA of 60% EtOH extract (μg/mL): na	
			Antioxidant: DPPH, ABTS, and malondialdehyde (MDA) assays α-glucosidase inhibition: α-glucosidase inhibitory assay			-Vitamin C as standard -IC ₅₀ of 60% EtOH extract: 409.71 μg/mL	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Stenocarpus sinuatus</i>	Leaves	Solvent extraction: MeOH Extracted crude extract was defatted with hexane to produce a hexane soluble fraction	Antityrosinase: Antityrosinase assay using L-DOPA as a substrate		-Kojic acid as standard	c) MDA assay: -Catechin as standard -IC ₅₀ of 60% EtOH extract: 16.56 µg/mL α-glucosidase inhibition: -Acarbose as positive control -IC ₅₀ : 60% EtOH extract: 46.29 µg/mL Acarbose: 216.05 µg/mL	82
<i>Tricholoposporium goniospermum</i>	Fruiting bodies	Preparation: Mycelium was isolated and cultured Solvent extraction for fruiting bodies and mycelia: <i>n</i> -hexane, EtOAc, MeOH Temperature: 20 °C	Antityrosinase: Colorimetric enzyme inhibition assays Antioxidant: DPPH, CUPRAC, and FRAP assays α-amylase and cholinesterase inhibition: Colorimetric enzyme inhibition assays	NR	- Tyrosinase inhibition IC ₅₀ (µg/mL): Hexane soluble fraction: 67.5 Kojic acid: 13.8 -Kojic acid as positive control -Tyrosinase inhibition (mg KAE/g extract): Fruiting bodies extracts:	Antioxidant: a) DPPH assay (mg TE/g extract): -Trolox as standard Fruiting bodies extracts: <i>n</i> -hexane: 83.80 ± 1.45 EtOAc: 554.30 ± 9.41 MeOH: 48.48 ± 0.07 Mycelia extracts: <i>n</i> -hexane: 127.76 ± 0.73 EtOAc: 412.81 ± 1.39 MeOH: 28.17 ± 0.39	83

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
						MeOH: 7.74 ± 0.69	
						b) CUPRAC assay (mg TE/g extract):	
						-Trolox as standard	
						Fruiting bodies extracts:	
						<i>n</i> -hexane: 53.92 ± 1.31	
						EtOAc: 307.71 ± 3.83	
						MeOH: 131.52 ± 0.67	
						Mycelia extracts:	
						<i>n</i> -hexane: 54.35 ± 0.92	
						EtOAc: 155.31 ± 1.85	
						MeOH: 129.60 ± 0.56	
						c) FRAP assay (mg TE/g extract):	
						-Trolox as standard	
						Fruiting bodies extracts:	
						<i>n</i> -hexane: 14.86 ± 1.21	
						EtOAc: 134.06 ± 1.50	
						MeOH: 20.54 ± 0.77	
						Mycelia extracts:	
						<i>n</i> -hexane: 15.15 ± 1.62	
						EtOAc: 74.26 ± 1.79	
						MeOH: 12.94 ± 1.33	
						Cholinesterase inhibition:	
						AChe Inhibition (mg GALAE/g extract):	
						No activity for all extracts	
						BChE Inhibition (mg GALAE/g extract):	
						-Galantamine as standard	
						Fruiting bodies extracts:	
						<i>n</i> -hexane: 5.48 ± 0.03	
						EtOAc: 26.78 ± 0.21	
						MeOH: 5.07 ± 0.02	
						Mycelia extracts:	
						<i>n</i> -hexane: 9.14 ± 0.07	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results				References
				Antimelanogenesis	Antityrosinase	Others		
<i>Vigna subterranea</i> (bambara groundnut (BG))	Hulls (H), seeds (S)	Extraction method (solvent extraction, temperature): Soxhlet extraction (95% EtOH, 60 °C), maceration extraction (95% EtOH, 37 °C), boiling (distilled water, 90 °C) BG-HS: Hull extracts prepared by Soxhlet	Antimelanogenesis: Melanin content assay using B16F10 murine melanoma cells Antityrosinase: Modified dopachrome method using L-tyrosine as a substrate Antioxidant: DPPH assay, metal chelating activity, modified Ferric-thiocyanate method to assess the lipid peroxidation activity	-Kojic acid as positive control	-Kojic acid as positive control	EtOAc: 25.21 ± 0.24 MeOH: 2.61 ± 0.01 α-amylase inhibition (mmol ACAE/g extract): -Acarbose as standard Fruiting bodies extracts: <i>n</i> -hexane: 0.55 ± 0.01 EtOAc: 2.97 ± 0.10 MeOH: 0.21 ± 0.01 Mycelia extracts: <i>n</i> -hexane: 0.73 ± 0.02 EtOAc: 2.25 ± 0.07 MeOH: 0.17 ± 0.01 Antioxidant:	84	
				-Melanin inhibition rate (%):	-Tyrosinase inhibition IC ₅₀ (mg/mL):	a) DPPH assay:		
				BG-HS: 22.69	BG-HS: 0.07 ± 0.07	-Ascorbic acid as standard		
				BG-HM: 72.90	BG-HM: 0.45 ± 0.23	-SC ₅₀ (mg/mL):		
				BG-HB: 32.15	BG-HB: 1.46 ± 0.30	BG-HS: 1.83 ± 0.16		
				BG-SS: na	BG-SS: 0.84 ± 0.27	BG-HM: 0.87 ± 0.02		
				BG-SM: 40.24	BG-SM: 0.64 ± 0.27	BG-HB: 1.18 ± 0.08		
				BG-HB: Hull extracts prepared by boiling	BG-SS: Seed extracts prepared by Soxhlet	BG-SM: Seed extracts prepared by maceration		BG-SB: Seed extracts prepared by boiling

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Vitis vinifera</i> L. (white grape pomace)	NR	Preparation: White pomace was either frozen (wet pomace, WP) or dried at 60 °C (dried pomace, DP)	Antityrosinase: Optimized enzyme inhibition assay using L-DOPA as a substrate	NR	EtOH extracts of both WP and DP showed stronger antityrosinase activity (inhibition rate of 63% to 79%) than H ₂ O extracts (inhibition rate of 43% to 71%). DP samples have good inhibition of tyrosinase compared to WP	BG-SS: 1.41 ± 0.09 BG-SM: 2.09 ± 0.06 BG-SB: 0.92 ± 0.15 Ascorbic acid: 0.04 ± 0.00 b) Metal chelating activity: -EDTA as standard -MC ₅₀ (mg/mL): BG-HS: 7.21 ± 0.76 BG-HM: 1.83 ± 0.09 BG-HB: 0.88 ± 0.16 BG-SS: 3.39 ± 0.53 BG-SM: 7.23 ± 0.32 BG-SB: 0.63 ± 0.04 EDTA: 0.73 ± 0.08 c) Modified ferric-thiocyanate method: -a-tocopherol as standard -LC ₅₀ (mg/mL): BG-HS: 3.79 ± 0.38 BG-HM: 0.70 ± 0.06 BG-HB: 0.83 ± 0.20 BG-SS: 4.68 ± 0.36 BG-SM: 3.56 ± 0.94 BG-SB: 6.93 ± 1.05 a-Tocopherol: 0.61 ± 0.06 Antioxidant: H ₂ O and EtOH extracts of WP had higher antioxidant activity than DP samples. However, EtOH extracts of both WP and DP showed stronger antioxidant activity than H ₂ O extracts	85
<i>Vitis vinifera</i> L. (white grape pomace)	NR	Solvent extraction: H ₂ O, EtOH	Antioxidant: ABTS assay	NR	EtOH extracts of both WP and DP showed stronger antityrosinase activity (inhibition rate of 63% to 79%) than H ₂ O extracts (inhibition rate of 43% to 71%). DP samples have good inhibition of tyrosinase compared to WP	Anti-inflammatory: H ₂ O extract of DP has a higher anti-inflammatory activity than DP while there was no activity reported for ethanol extracts	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Ziziphora taurica</i> subsp. <i>cleonoides</i>	Aerial parts	Solvent extraction: EtOAc, MeOH, H ₂ O	Anti-inflammatory activity: Bioluminescent cell-based assay performed using HEK293 cells				86
			Antityrosinase: Mushroom tyrosinase activity assay	NR	-Kojic acid as positive control	Antioxidant:	
			Antioxidant: DPPH, ABTS, CUPRAC, FRAP, PM, ferrous chelating assays		-Tyrosinase inhibition IC ₅₀ (mg/mL):	a) DPPH assay:	
			Enzyme inhibition activity: α -amylase inhibition evaluated by Caraway IKI method		EtOAc: 1.40 $\pm$ 0.06 MeOH: 1.25 $\pm$ 0.01	-BHA as standard	
					H ₂ O: 2.71 $\pm$ 0.42 Kojic acid: 0.37 $\pm$ 0.02	-IC ₅₀ (mg/mL): EtOAc: 10.60 $\pm$ 0.79 MeOH: 4.75 $\pm$ 0.12 H ₂ O: 4.98 $\pm$ 0.15 BHA: 0.32 $\pm$ 0.01 b) ABTS assay: -BHA as standard -IC ₅₀ (mg/mL): EtOAc: 4.11 $\pm$ 0.09 MeOH: 2.66 $\pm$ 0.02 H ₂ O: 2.61 $\pm$ 0.26 BHA: 0.25 $\pm$ 0.01 c) CUPRAC assay: -BHA as standard -IC ₅₀ (mg/mL): EtOAc: 1.80 $\pm$ 0.03 MeOH: 1.97 $\pm$ 0.02	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
Ziziphus jujuba	Seeds	Preparation: Flavonoid glycosides were isolated from the seeds which were jujuboside A (JUA), jujuboside B (JUB), epicanothic acid (EPA), betulin (BTL), and 6''-feruloylspinosin (FRS),	Antimelanogenesis: Quantification of extracellular and intracellular melanin content	-Phenylthiourea (PTU) as positive control	-PTU as positive control	H ₂ O: 2.49 ± 0.06 BHA: 0.30 ± 0.01 d) FRAP assay: -BHA as standard -IC ₅₀ (mg/mL): EtOAc: 2.99 ± 0.26 MeOH: 1.14 ± 0.06 H ₂ O: 1.54 ± 0.15 BHA: 0.25 ± 0.01 e) PM assay: -BHA as standard -IC ₅₀ (mg/mL): EtOAc: 1.52 ± 0.02 MeOH: 1.82 ± 0.15 H ₂ O: 2.71 ± 0.26 BHA: 0.35 ± 0.01 f) Ferrous chelating assay: -EDTA as standard -IC ₅₀ (mg/mL): EtOAc: 6.47 ± 0.67 MeOH: 1.66 ± 0.02 H ₂ O: 1.04 ± 0.01 EDTA: 0.034 ± 0.001 α-amylase inhibition: -Acarbose as positive control -IC ₅₀ (mg/mL): EtOAc: 1.95 ± 0.04 MeOH: 3.97 ± 0.08 H ₂ O: 36.99 ± 0.13 Acarbose: 1.21 ± 0.07 NR	7

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
<i>Zizyphus lotus</i>	Leaves, fruits	Solvent extraction: H ₂ O	assay using B16F10 melanoma cells				
			Antityrosinase: <i>in vitro</i> mushroom tyrosinase activity assay	-Extracellular melanin content was inhibited from 147.7 ± 5.2 % to: JUB: 117.4 ± 0.5% EPA: 119.9 ± 2.0 % FRS: 106.8 ± 1.9 % PTU: 92.4 ± 2.4% -Intracellular melanin content was inhibited from 153.5 ± 3.3 % to: JUB: 114.7 ± 1.5% EPA: 113.8 ± 2.1 %, FRS: 101.4 ± 2.9 % PTU: 95.3 ± 30.2 %	-Inhibitory rate of mushroom tyrosinase activity (%): JUA: 7.4 ± 5.3 JUB: 33.9 ± 4.5 EPA: 38.4 ± 3.1 BTL: 11.2 ± 5.1 FRS: 45.7 ± 2.7 PTU: 58.4 ± 1.0		
			Antityrosinase: Tyrosinase inhibition assay using L-DOPA as a substrate	NR	-Quercetin as positive control	Antioxidant:	87
			Antioxidant: DPPH, ABTS, and FRAP assays		-Tyrosinase inhibition IC ₅₀ (μg/mL): Fruits: 70.23 ± 5.94 Leaves: 129.11 ± 9.40 Quercetin: 246.90 ± 1.90	a) DPPH assay (mg TE/g extract): -Trolox as standard	
			Antidiabetics: α-amylase and α-glucosidase inhibitory assays			-IC ₅₀ : Fruits: 74.87 ± 16.74 Leaves: 241.75 ± 17.37 b) FRAP assay (mg AAE/g extract): -Ascorbic acid as standard	

Table 1. continued

Plant name	Parts	Sample preparation and extraction methods	Biology assays	Results			References
				Antimelanogenesis	Antityrosinase	Others	
					-IC ₅₀ : Fruits: 55.30 ± 2.30 Leaves: 160.10 ± 2.30 c) ABTS assay (mg TE/g extract): -Trolox as standard -IC ₅₀ : Fruits: 46.31 ± 11.02 Leaves: 301.34 ± 8.26 Antidiabetic activity: α -amylase inhibition: -Acarbose as positive control -IC ₅₀ (μ g/mL): Fruits: 31.91 ± 1.53 Leaves: 20.40 ± 1.30 Acarbose: 396.42 ± 3.54 α -glucosidase inhibition: -Acarbose as positive control -IC ₅₀ (μ g/mL): Fruits: 27.95 ± 2.45 Leaves: 8.66 ± 0.62 Acarbose: 199.53 ± 2.45		

^aNR: Not reported. NA: No activity. BHA: Butylated hydroxyanisole. BHT: Butylated hydroxytoluene. AChE: Acetylcholinesterase. BChE: Butyrylcholinesterase. ACaE: Acarbose equivalent. TE: Trolox equivalent. EDTAE: Ethylenediaminetetraacetic acid equivalent. GALAE: Galantamine equivalent. KAE: Kojic acid equivalent. AEAC: Ascorbic acid equivalent. PM: Phosphomolybdenum assay. DPPH: 2,2-diphenyl-1-picrylhydrazyl. ABTS: 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic) acid. CUPRAC: cupric-reducing antioxidant capacity. FRAP: Ferric reducing antioxidant power assay.

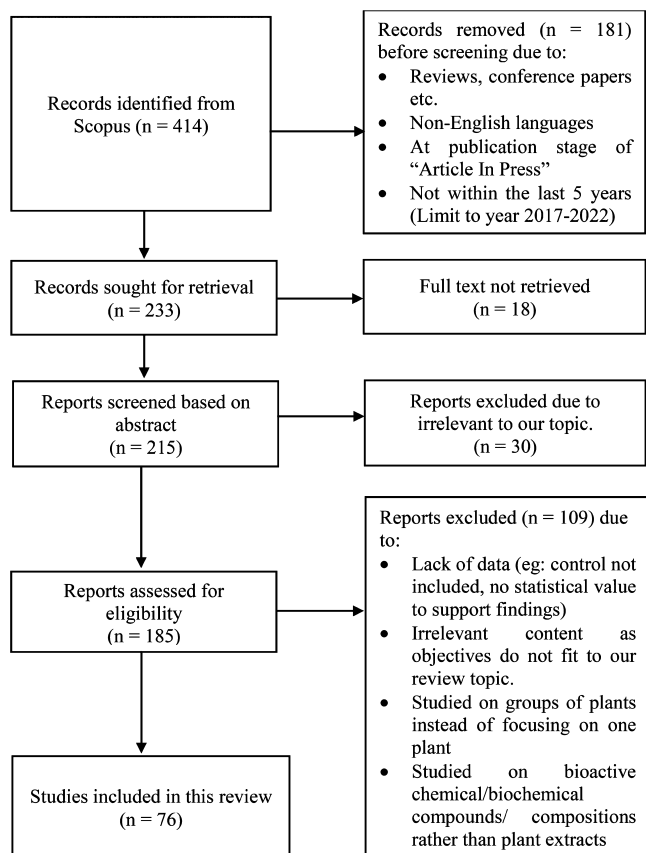


Figure 1. PRISMA flow diagram of the systematic review.

alcohol is much more effective than water for phytochemical extraction due to its ability to extract polar compounds and some nonpolar compounds.

Ethanol is one of the most suitable solvent extractions that can extract both polar compounds and nonpolar compounds. Ethanol was being used to extract the bioactive compounds from *Acer rubrum*, *Achillea biebersteinii*, *Achillea filipendulina*, *Aerva lanata* (L.) Juss., *Allium ursinum*, *Artemisia asiatica*, *Artemisia capillaris*, *Aurea helianthus*, *Cymbidium* sp. (Orchidaceae), *Cytinus hypocistis*, *Dalea pazensis* Rusby, *Erica arborea* L., *Fagus sylvatica* L., *Hippophae rhamnoides* L., *Kadsura coccinea*, *Kummerowia striata*, *Lepechinia meyenii*, *Morus alba* L., *Myrica rubra*, *Persicaria orientalis*, *Phyllostachys nigravar henosis*, *Potentilla anserina* L., *Potentilla paradoxa* Nutt., *Prasiola japonica*, *Pterocarpus marsupium*, *Rosa chinensis* cv. "JinBian", *Schisandra chinensis* (Turcz.) Baillon, *Sorghum bicolor*, *Vigna subterranea*, and *Vitis vinifera* L. The ethanol used in these extractions of plants was from 25% ethanol in water up to 100%. By mixing ethanol with water, this can extract bioactive compounds with a wider polarity due to the ethanol solvent polarity being influenced by the high concentration of water contained in ethanol.

Water is widely utilized as solvent for extraction because it is the most polar and greenest solvent. It is nontoxic to human health and the environment, cost-effective, and safe to use.¹⁹ Among the included articles, water was used to extract the bioactive compounds from *Achillea biebersteinii* and *Aerva lanata* (L.) Juss., *Allium ursinum*, *Aronia melanocarpa*, *Camellia oleifera* Abel, *Celastrus hindsii*, *Cosmos caudatus* Kunth, *Cymbidium* sp. (Orchidaceae), *Cytinus hypocistis*, *Dendropanax morbiferus* H. Lev, *Dimocarpus longan* Lour., *Fagus sylvatica* L.,

Garcinia atroviridis Griff. ex. T. Anderson, *Juglans mandshurica*, *Leonurus japonicus*, *Limonium delicatulum*, *Lophira lanceolata* Tiegh. ex Keay, *Manilkara kauki*, *Myrica rubra*, *Nardostachys jatamansi*, *Nepeta glomerulosa* Boiss., *Pistacia atlantica* subsp. *Mutica*, *Rubus cesius* L., *Schisandra chinensis* (Turcz.) Baillon, *Scorzonera tomentosa* L., *Vitis vinifera* L., and *Ziziphora taurica* subsp. *Cleonioides* and *Zizyphus lotus*. It was used as a single solvent or commonly mixed with ethanol, methanol, or acetone. Further, properties of water extracts can be improved by increasing the temperature.¹⁹ Boiling water has been used as an extract solvent for *Carapa procera*, *Phyllostachys nigravar. Henosis*, *Vigna subterranea*, and *lotus*.

Methanol generally produces higher extraction yields and extracts more phytochemical constituents due to its higher polarity than ethanol. Based on the study review, methanol extracts produce better results in terms of the biological activities. Methanol was used to extract the following plants: *Camellia oleifera* Abel, *Carapa procera*, *Celastrus hindsii*, *Clausena indica*, *Galla rhois*, *Granny Smith apple*, *Juglans mandshurica*, *Leonurus japonicus*, *Limonium delicatulum*, *Lophira lanceolata* Tiegh. ex Keay, *Maclura tricuspidata*, *Manilkara kauki*, *Nardostachys jatamansi*, *Nepeta glomerulosa* Boiss., *Olea europaea*, *Pelargonium graveolens*, *Persicaria orientalis*, *Phyllanthus phillyreifolius*, *Phyllostachys nigravar. Henosis*, *Pistacia atlantica* subsp. *mutica*, *Pistacia lentiscus* L., *Rubus cesius* L., *Scabiosa columbaria*, *Schinus terebinthifolius*, *Scorzonera tomentosa* L., *Stenocarpus sinuatus*, *Tricholysporum goniospermum*, and *Ziziphora taurica* subsp. *Cleonioides*. The methanol used in the extractions of plants was from 50% in water up to 100%.

Acetone, butanol, ethyl acetate, and dichloromethane are also regarded as polar solvents but much less polar than ethanol, methanol, and water. Hence, they can extract a mixture of both polar and nonpolar components. From the studies reviewed, acetone has been used to extract *Acanthus ilicifolius*, *Cinnamomum camphora*, *Dimocarpus longan* Lour., *Melastoma normale*, *Nardostachys jatamansi*, *Photinia fraseri*, *Polygonum maritimum* L., and *Schinus terebinthifolius*, whereas butanol had extracted *Kummerowia striata*, *Maclura tricuspidata*, *Morus alba* L., *Nepeta glomerulosa* Boiss., *Pistacia atlantica* subsp. *Mutica*, *Rubus cesius* L., and *Schisandra chinensis* (Turcz.) Baillon. The acetone used for extraction was from 70% in water up to 100%. Moreover, ethyl acetate was used to extract the following plants: *Asparagus cochinchinensis*, *Celastrus hindsii*, *Cinnamomum camphora*, *Clausena indica*, *Cymbidium* sp. (Orchidaceae), *Dalea pazensis* Rusby, *Juglans mandshurica*, *Kummerowia striata*, *Leonurus japonicus*, *Maclura tricuspidata*, *Melastoma normale*, *Morus alba* L., *Nepeta glomerulosa* Boiss., *Persicaria orientalis*, *Phyllanthus phillyreifolius*, *Phyllostachys nigravar. Henosis*, *Pistacia atlantica* subsp. *Mutica*, *Potentilla anserina* L., *Rubus cesius* L., *Schisandra chinensis* (Turcz.) Baillon, *Scorzonera tomentosa* L., *Tricholysporum goniospermum*, *Ziziphora taurica* subsp. *Cleonioides*, dichloromethane-extracted *Cymbidium* sp. (Orchidaceae), *Kummerowia striata*, *Maclura tricuspidata*, *Nepeta glomerulosa* Boiss., *Pelargonium graveolens*, *Pistacia atlantica* subsp. *Mutica*, *Schisandra chinensis* (Turcz.) Baillon, and *Scorzonera tomentosa* L.

Compared with polar solvents, there were fewer studies using nonpolar solvents. Based on the studies reviewed, nonpolar solvents used by the studies are chloroform, acetonitrile, *n*-hexane, benzene, 1,3-butanediol, oil, and petroleum ether. Chloroform was used as a single solvent or combined in use with ethanol to extract *Dalea pazensis* Rusby, *Juglans*

mandshurica, and *Nardostachys jatamansi*. Hexane has been used to extract the following plants: *Celastrus hindsii*, *Clausena indica*, *Dalea pazensis* Rusby, *Leonurus japonicus*, *Maclura tricuspidata*, *Morus alba* L., *Nepeta glomerulosa* Boiss., *Pelargonium graveolens*, *Persicaria orientalis*, *Phyllostachys nigravar.* *Henosis*, *Pistacia atlantica* subsp. *mutica*, *Schinus terebinthifolius*, *Schisandra chinensis* (Turcz.) Baillon, *Scorzonera tomentosa* L., *Stenocarpus sinuatus*, and *Tricholoposporum goniospermum*. There was only one study each for acetonitrile, 1,3-butanediol, and benzene solvents for extraction, which are *Nardostachys jatamansi*, *Camellia oleifera* Abel, and *Dalea pazensis* Rusby, respectively. Essential oils were isolated from *Achillea filipendulina* and *Beta vulgaris* subsp. *Maritime* (L.) Arcang., *Melaleuca quinquenervia*, *Pistacia atlantica* subsp. *Mutica*, and *Schinus terebinthifolius* by subjecting to hydro-distillation. Essential oils are known for having numerous amounts of bioactive compounds. Petroleum ether was also utilized to extract *Cinnamomum camphora*, *Dimocarpus longan* Lour., *Melastoma normale*, *Potentilla anserina* L., and *Rosa chinensis* cv. "JinBian".

Other than solvent extraction, bioactive compounds also can be extracted using various conventional (classical) and nonconventional (innovative) methods. The methods that were used to extract bioactive compounds according to the studies reviewed included fractionation, accelerated solvent extraction (ASE) or pressurized solvent extraction (PLE), maceration (M), ultrasonic-assisted extraction (UAE), shaking extraction (SE), infusion, microwave-assisted extraction (MAE), Soxhlet (SOE), homogenizer-assisted extraction (HAE), pulsed electric field (PEF), and decoction. Among the methods described above, fractionation is most frequently used by separating plant extracts into various fractions. The fractions are then used to further isolate the bioactive compounds.²⁰ Extracts that were subjected to fractionation from the following plants were *Achillea biebersteinii*, *Celastrus hindsii*, *Clausena indica*, *Dalea pazensis* Rusby, *Juglans mandshurica*, *Leonurus japonicus*, *Lepechinia meyenii*, *Maclura tricuspidata*, *Melastoma normale*, *Morus alba* L., *Pistacia atlantica* subsp. *Mutica*, *Potentilla anserina* L., *Schisandra chinensis* (Turcz.) Baillon, and *Stenocarpus sinuatus*.

In the Soxhlet extraction method, the plant sample was first placed in the thimble chamber of the Soxhlet apparatus. The extraction solvent was heated in a round-bottom flask, vaporized into a sample timber, condensed in the condenser, and dripped back into the extract sample. A siphon was then used to aspirate the mixtures of solvent and extracts and emptied into the round-bottom flask to mix with the clean solvents.²¹ In the included articles, the following plants are mentioned: *Erica arborea* L., *Lophira lanceolata* Tiegh. ex Keay, *Phyllanthus phillyreifolius*, and *Vigna subterranea* were extracted by this technique. The Soxhlet has several advantages including required smaller volume of solvents, simple to use, low-cost equipment, lack of filtration, and continuous contact between the solvent and the sample.²¹ In addition, maceration is a method that immerses the plant materials in extracting solvent in a stoppered container. The mixture was then incubated for 2 to 3 days at room temperature with constant stirring to obtain the plant extracts.²⁰ Plant parts of *Achillea biebersteinii*, *Achillea filipendulina*, *Carapa procera*, *Erica arborea* L., *Lophira lanceolata* Tiegh. ex Keay, *Morus alba* L., *Phyllanthus phillyreifolius*, and *Vigna subterranea* were extracted by this method. Although this method is time consuming, it is still

widely used because it is an easy to use and inexpensive method.

ASE and PLE are nonconventional methods introduced as an alternative to maceration and Soxhlet extraction. They are automated methods using liquid solvents to extract under elevated pressures and temperatures.²² ASE or PLE was used to extract *Achillea biebersteinii*, *Erica arborea* L., and *Pistacia lentiscus* L. Furthermore, infusion applied a principle similar to maceration and decoction by soaking the plant material in solvents. *Carapa procera* and *L. lanceolata* Tiegh. ex Keay used infusion as an extraction method. Moreover, MAE uses microwave energy that results in rapid heating extraction of *Erica arborea* L. and *Fagus sylvatica* L..²³ UAE was used to extract *Achillea biebersteinii* and *Erica arborea* L. Other methods that have been mentioned, which are SE, HAE, PEF, and decoction, had only been used by one study each, respectively, to extract *Achillea biebersteinii*, *Lophira lanceolata* Tiegh. ex Keay, *Morus alba* L., and *Phyllanthus phillyreifolius*, respectively.

4. BIOLOGICAL ACTIVITIES

Biological activities such as antimelanogenesis, antityrosinase, antioxidant, and anti-inflammatory various natural plant species are summarized and tabulated in Table 1.

In order to pursue natural novel melanin inhibitors with fewer side effects, the investigation of various natural plant species has prompted the identification of numerous plant extracts or bioactive compounds that have the potential to be used as skin-whitening agents. Based on the studies we reviewed, the antimelanogenesis of natural plants was evaluated using melanin content assay in B16 melanoma cell lines, A375.S2 melanoma cells, and A2058 human melanoma cells. The effectiveness of melanogenesis inhibition was expressed as IC₅₀ values, percentage of the control, and percentage of melanin inhibitory effects. IC₅₀ values represent the concentration of extract required to inhibit melanin synthesis by 50%. Kojic acid and arbutin were commonly used as a positive control.

Tyrosinase is a multifunctional copper-containing enzyme that is commonly found in microorganisms, animals, and plants.⁸⁸ It is an essential enzyme in the melanin biosynthesis pathway and has always been a popular target to be used as melanogenesis inhibitors. Based on the studies we reviewed, the antityrosinases of natural plants were evaluated using the tyrosinase activity assay or mushroom tyrosinase activity assay using L-tyrosine and/or L-DOPA as substrates, the dopachrome method using L-DOPA as a substrate, and cellular tyrosinase activity assay using B16 melanoma cell lines. The effectiveness of tyrosinase inhibition was expressed as IC₅₀ values, EC₅₀ values, milligrams of kojic acid equivalent per gram of dry extract, and percentage of tyrosinase inhibitory effects. IC₅₀ values represent the concentration of extract required to inhibit tyrosinase activity by 50%, while EC₅₀ values represent the concentration of extract required to produce a half-maximal response. Kojic acid, arbutin, and ascorbic acid were commonly used as a positive control.

Antioxidants are molecules that neutralize free radicals by donating electrons to them. These can help to prevent cellular damage through their free radical scavenging ability.⁸⁹ Plants are found to comprise a variety of natural antioxidants that may have the potential to protect humans from UV-induced disorders. Based on the studies we reviewed, the antioxidant activities of natural plants were evaluated using a number of assays with six commonly used assays including 2,2-diphenyl-1-picrylhydrazyl (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic) acid

(ABTS), cupric-reducing antioxidant capacity (CUPRAC), ferric-reducing antioxidant power assay (FRAP), metal chelating, and a phosphomolybdenum assay (PM). The effectiveness of antioxidant activity was generally expressed as IC_{50} values, EC_{50} values, percentage of free radical scavenging ability, millimoles of Trolox equivalent per gram of dry extract, and milligrams of ethylenediaminetetraacetic acid equivalent per gram of dry extract. BHT, ascorbic acid, BHA, Trolox, and Vitamin C were commonly used as standards for DPPH, ABTS, FRAP, CUPRAC, and PM assays, whereas EDTA was used as a standard for the metal-chelating assay.

Other than depigmentation effects, anti-inflammatory and enzyme inhibitory activities such as cholinesterase, α -amylase, α -glucosidase, elastase, and collagenase inhibition were also commonly evaluated by researchers. Inflammation occurs in the body in response to tissue injury, cell death, and cancer or when infectious microorganisms such as bacteria, viruses, or fungi enter our body.⁹⁰ Inflammation can result in common symptoms including redness, swelling, heat, and pain; thus, anti-inflammatory activity plays a significant function in alleviating these symptoms. The anti-inflammatory activities of natural plant species were performed using several types of assays, but the assay commonly used to examine the anti-inflammatory activity is the assessment of nitric acid production using LPS-stimulated RAW 264.7 macrophages.

4.1. *Acanthus ilicifolius*. The antityrosinase and antioxidant activities of the condensed tannins (CT_s) of *A. ilicifolius* leaves were explored by Gong et al.²⁴ The tyrosinase inhibitory activity of *A. ilicifolius* leaves of CT_s was found to be comparable to the positive control, arbutin, with IC_{50} values of $19.7 \pm 0.13 \mu\text{g/mL}$ and 10.89 mg/mL , respectively, on mushroom tyrosinase activity assay. This result indicated the high potential of *A. ilicifolius* CT_s in tyrosinase inhibition activity. The antioxidant effects of CT_s from *A. ilicifolius* were reflected in the DPPH, ABTS, and FRAP assays, compared with ascorbic acid as a standard antioxidant. The EC_{50} values of DPPH and ABTS scavenging activities were $104 \pm 0.894 \mu\text{g/mL}$ and $86 \pm 0.616 \mu\text{g/mL}$, respectively, which were higher than that of ascorbic acid equivalent under the same conditions,²⁴ and the FRAP value was $758.28 \pm 2.42 \text{ mg of AAE/g}$, indicating the high antioxidant activities of the CT_s from *A. ilicifolius*.²⁴

4.2. *Achillea biebersteinii*. Strzepek-Gomolka et al. were the first to report the antimelanogenesis activity of *A. biebersteinii* flower extracts in mammalian cells. The results showed that fractions 25 and 27 obtained from the extracts using the ASE method reduced the release of melanin from B16F10 murine melanoma cells stimulated with α -melanocyte-stimulating hormone (α -MSH), without affecting the viability and morphology of the cells.²⁵ In view of the tyrosinase inhibitory activity of *A. biebersteinii* flower extracts, the most significant mushroom tyrosinase inhibitory activity was found in fractions 5, 6, and 7, displaying 34.9, 24.3, and 31.5% inhibitory activity, respectively.²⁵ While fractions 25 and 27 showed the most significant murine tyrosinase inhibition of about 80% murine tyrosinase inhibitory activity, which was higher than kojic acid, the control tyrosinase inhibitor at the same conditions was about $100 \mu\text{g/mL}$. However, the extracts obtained by UAE and SE had better antioxidant activity than extracts obtained by ACE and maceration.²⁵

4.3. *Achillea filipendulina*. Asghari and co-workers investigated the cholinesterase, α -amylase, and α -glucosidase inhibition activity of ethanol extracts and essential oils of

Achillea filipendulina flowers and leaves using enzyme inhibition assays. Overall, ethanol extracts were found to be able to inhibit cholinesterase, α -amylase, and α -glucosidase more efficiently compared to essential oil. Ethanol flowers and leaf extracts presented the highest inhibitory effects against α -amylase ($1.91 \pm 0.05 \text{ mmol ACE/g extract}$) and α -glucosidase ($2.97 \pm 0.06 \text{ mmol ACE/g extract}$), respectively.²⁶ Ethanol flower extract demonstrated strong inhibitory effects against acetylcholinesterase and butyrylcholinesterase (AChE: $2.46 \pm 0.06 \text{ mmol GALAE/g extract}$; BChE: $3.65 \pm 0.07 \text{ mmol GALAE/g extract}$). Lastly, antielastase and anticollagenase activities can contribute to antiaging activity. The inhibition of cholinesterase including acetylcholinesterase and butyrylcholinesterase is able to effectively treat Alzheimer's disease since cholinesterase inhibitors were commonly prescribed to treat Alzheimer's disease. Also, α -amylase inhibition and α -glucosidase inhibition can be used as a therapeutic approach to treat diabetic patients by reducing the rate of glucose absorption.^{26,68} Enzyme inhibitory activities were commonly evaluated using the colorimetric method or enzyme inhibition assays. Galantamine was used as a positive control for cholinesterase inhibition, while acarbose was used as a positive control for α -amylase and α -glucosidase inhibition. Furthermore, ethanol extracts of *A. filipendulina* flowers and leaves were reported with promising tyrosinase inhibitory effects with values of 23.97 and 24.41 mg KAEs/g extract, respectively.²⁶ On the other hand, the antioxidant activities of ethanol extracts and essential oils of *Achillea filipendulina* flowers and leaves were evaluated by DPPH, ABTS, PM, and metal chelating assays. Ethanol extracts of *A. filipendulina* flowers and leaves exhibited strong antiradical effects with values of 53.93 and 51.70 mg TE/g sample for DPPH assays and 43.47 and 35.03 mg TE/g sample for ABTS assays, respectively. The radical scavenging activity of flowers and leaves of essential oils against DPPH were moderate with values of 25.87 and 22.13 mg TE/g sample, respectively. This trend was also observed in the abilities of essential oils of flowers (18.23 mg TE/g sample) and leaves (15.40 mg TE/g sample) in scavenging ABTS radicals. The ethanol extracts of *A. filipendulina* flowers and leaves exhibited stronger antioxidant effects in total antioxidant (84.03 and 70.17 mg AAEs/g sample) and metal chelating assays (37.13 and 30.47 mg EDTAEs/g sample) than the essential oils. In all types of antioxidant assays, flower extract showed higher activity than those of leaves.²⁶

4.4. *Aerva lanata* (L.) Juss. Pieczykolan et al. evaluated the antiaging activity of *Aerva lanata* (L.) Juss extracts using elastase and collagenase inhibition assays.²⁷ The researchers found that 50% ethanol extract at 180 °C exhibited the highest antielastase and anticollagenase activities with EC_{50} values of 35.81 ± 0.81 and $21.76 \pm 1.27 \text{ mg/mL}$, respectively. The highest antityrosinase activity was found in 80% ethanol extract at 60 °C with the EC_{50} of $43.32 \pm 0.57 \mu\text{g/mL}$, which is comparable with the positive control, kojic acid with an EC_{50} of $28.42 \pm 0.11 \mu\text{g/mL}$. Notably, water extract at 60 °C showed the highest EC_{50} value of tyrosinase inhibition with $155.97 \pm 1.34 \mu\text{g/mL}$. The 80% ethanol extract (180 °C) exhibited the highest DPPH (119.85 mg of Trolox/g DE) and ABTS (107.58 mg of Trolox/g DE) scavenging activity. The lowest antioxidant properties in both tests were obtained when 100% ethanol was used as a solvent: 9.17 mg of Trolox/g of DE at 80 °C (DPPH) and 9.90 mg of Trolox/g of DE at 60 °C (ABTS). The 100% ethanol extract at 60 °C showed the greatest metal chelating activity with an EC_{50} value of $1.58 \pm 0.17 \text{ mg/mL}$. The highest value of oxygen radical absorbance

capacity was determined in the extract obtained in 50% ethanol at 180 °C with a value of 3.84 ± 0.06 mM TE/g.²⁷

4.5. *Allium ursinum*. Nikkhahi et al. explored the antioxidant and tyrosinase inhibitory activities of *A. ursinum* extracts by using DPPH and mushroom tyrosinase assays.²⁸ From the results obtained, the water extract showed the highest DPPH radical scavenging activity with a SC_{50} (values of active DPPH scavengers) of 0.471 mg/mL, compared to 70% ethanol extract (0.532 mg/mL) and 100% ethanol extract (0.643 mg/mL). The SC_{50} of ascorbic acid (positive standard) was 0.008 μ /mL. On the other hand, the 70% ethanol extract exhibited the highest antityrosinase activity compared to water extract and 100% ethanol extract, with IC_{50} values of 0.392, 0.414, and 0.402 mg/mL, respectively. The positive control, kojic acid, indicated an IC_{50} value of 0.031 mg/mL in this study.²⁸

4.6. *Aronia melanocarpa*. Based on Svarc-Gajic et al., the antityrosinase activity of the subcritical water extracts of chokeberry (*A. melanocarpa*) stems was calculated to be 15.87 ± 3.82 mg KAE/g extract by using the dopachrome method, while kojic acid was used as the positive control.²⁹ In the same study, the antioxidant activity of the chokeberry stem extracts was determined using the DPPH assay and reducing power tests. The IC_{50} values of chokeberry stem extracts in the DPPH assay and reducing power assay were reported as 0.10 ± 0.02 mg/mL and 1.25 ± 0.03 mg/mL, respectively.²⁹

4.7. *Artemisia asiatica*. The antimelanogenesis and antityrosinase activities of 95% ethanol extract of *Artemisia asiatica* were reported by Jeong et al.³⁰ The studies found that the ethanol extract significantly suppressed melanin secretion and decreased the melanin content in α -MSH-stimulated B16F10 cells in a dose-dependent manner; the suppressive effect was comparable to the arbutin, the positive control in this study. Furthermore, the ethanol extract was found to inhibit both the mushroom and B16F10 cellular tyrosinase activity in a dose-dependent manner, and a stronger tyrosinase inhibitory effect than arbutin was reported.³⁰

4.8. *Artemisia capillaris*. Woo et al. explored the *in vitro* antimelanogenesis and antityrosinase effects of *Artemisia capillaris* (100% ethanol extract) in different concentrations on B16F10 melanoma cells.³¹ The results obtained showed that the extract reduced the cellular melanin content in a dose-dependent manner in α -MSH-stimulated B16F10 cells, with a 40.24% inhibition at 50 μ g/mL. Besides, the ethanol extract also significantly decreased cellular tyrosinase activity in a dose-dependent manner, with a 30.92% inhibition at 50 μ g/mL reported.³¹

4.9. *Asparagus cochinchinensis*. Wang et al. examined the fermented and unfermented *Asparagus cochinchinensis* root extracts in antimelanogenesis, antityrosinase, and antioxidant activities. The published results show that both fermented and unfermented extracts inhibited melanogenesis in human epidermal melanocytes (HEMs) and the human malignant melanoma cell line A375.S2 in a dose-dependent manner.³² In the mushroom tyrosinase activity assay, fermented extracts were significantly higher than the unfermented extracts, with IC_{50} values of 50.6 ± 3.1 and 527.3 ± 23.6 mg/L, respectively. By contrast, the IC_{50} values of the antityrosinase activity for the positive controls kojic acid and α -arbutin were 18.6 ± 0.5 and 261.4 ± 12.8 mg/L, respectively.³² Similarly, the results of cellular antityrosinase activity were $48.6\% \pm 1.8\%$ – $55.8\% \pm 2.3\%$ and $3.6\% \pm 2.0\%$ – $28.4\% \pm 1.3\%$ for the fermented and unfermented extracts, respectively, at a 1000 mg/L concentration.

The fermented extract exhibited stronger radical scavenging activity with IC_{50} values of 250.6 ± 32.5 mg/L for the DPPH assay and 25.7 ± 3.5 mg/L for the reducing power assay compared to the unfermented extract (DPPH assay: 586.9 ± 86.1 mg/L; reducing power assay: 59.0 ± 6.2 mg/L). The butylated hydroxytoluene (BHT) was used as a positive control (IC_{50} : 105.3 ± 285.6 mg/L) in the DPPH assay, while beta hydroxy acid (BHA) (IC_{50} : 35.4 ± 2.6 mg/L), ascorbic acid (IC_{50} : 76.8 ± 6.2 mg/L), and α -tocopherol (IC_{50} : 53.2 ± 3.7 mg/L) were the standards for reducing the power assay.³²

4.10. *Aurea helianthus*. According to Kim et al., the *Aurea helianthus* stem extract was found to exhibit an antimelanogenesis effect by reducing the melanin content by 20% in α -MSH-stimulated B16 melanoma cells. The extract was reported to inhibit the cellular tyrosinase activity in a dose-dependent manner in B16 cells.⁴

4.11. *Beta vulgaris* subsp. *Maritima* (L.) Arcang. Zardi-Bergaoui et al. reported the antityrosinase activity of hydrodistilled essential oil of the aerial parts of *B. vulgaris*, with an inhibition rate of 67% ($cc = 100$ μ g/mL) compared to the positive standard, kojic acid (85%, 50 μ g/mL).³³ The essential oil exhibited a significantly higher antioxidant activity according to the DPPH radical scavenging assay with an IC_{50} of 0.055 ± 0.006 mg/mL when compared to the BHT reference value of 0.018 ± 0.010 mg/mL. Similarly, in the ABTS and reducing power assays, the essential oil had reported IC_{50} values of 0.079 ± 0.010 and 0.120 ± 0.002 mg/mL, comparable to the BHT reference value of 0.050 ± 0.0 and 0.020 ± 0.010 mg/mL, respectively.³³ On the other hand, the study demonstrated significant activity of the enzyme catalase in the oil (524.447 ± 2.58 μ /mg protein) as compared to vitamin C (747.384 ± 016). In view of the paraoxonase test, the essential oil exhibited an interesting activity (55.0 ± 1.5 μ M/min/L) comparable to that of ascorbic acid (55 ± 0.2 μ M/min/L).³³

4.12. *Camellia oleifera* Abel. Liu et al. evaluated the antityrosinase activity of *Camellia oleifera* Abel shell extracts by different solvent extraction. The results showed that the 1,3-butanediol extract has the highest tyrosinase inhibition rate of 71.9%, compared to those of the methanol extract (49.2%) and water extract (39.3%). Kojic acid was used as the positive control in this study.³⁴

4.13. *Carapa procera*. According to Sinan et al., the tyrosinase inhibition activity of *Carapa procera* leaf extract was found as 73.43 ± 0.07 mg KAE/g extract, while the stem barks were reported to be 75.25 ± 0.20 mg KAE/g extract.³⁵ In general, methanol extract of stem bark had the highest antioxidant activity in all tested assays with 3.14 ± 0.01 mmol of TE/g of the ABTS assay, 4.47 ± 0.07 mmol of TE/g of the CUPRAC assay, and 2.15 ± 0.01 mmol of TE/g of the FRAP assay. Methanol extracts of both plant parts exhibited moderate inhibitory activity against α -glucosidase (0.95 ± 0.01 mmol ACAE/g) and high inhibitory activity against α -amylase (0.77 ± 0.01 mmol ACAE/g). As for anticholinesterase assays, the methanolic extracts of the two parts gave the highest inhibitory effects on acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), respectively (leaves: 2.55 ± 0.02 and 4.16 ± 0.26 ; stem bark: 2.54 ± 0.01 and 4.58 ± 0.13 mg GALAE/g).³⁵

4.14. *Celastrus hindsii*. Viet et al. reported the antityrosinase and antioxidant activities of *Celastrus hindsii* leaf extracts (α -amyrin and β -amyrin).³⁶ The tyrosinase inhibition IC_{50} of α -amyrin and β -amyrin was 178.85 ± 3.28 μ g/mL, while the IC_{50} for positive control of kojic acid was $15.55 \pm$

2.28 $\mu\text{g/mL}$. The DPPH radical scavenging activity of α -amyrin and β -amyrin was $125.55 \pm 0.98 \mu\text{g/mL}$, and a value of $155.28 \pm 1.01 \mu\text{g/mL}$ for the ABTS assay was reported.³⁶ Both antioxidant assays were used BHT as a positive control, with the IC_{50} value of $8.22 \pm 0.89 \mu\text{g/mL}$ for the DPPH assay and $53.40 \pm 1.52 \mu\text{g/mL}$ for the ABTS assay, respectively.³⁶

4.15. *Cinnamomum camphora*. Yang et al. investigated the antityrosinase and antioxidant activities of *Cinnamomum camphora* leaf and branch extracts.³⁷ The results found that the leaves exhibited higher antityrosinase activities in both monophenolase and diphenolase assays with an inhibition IC_{50} of 167 ± 18 and $70 \pm 7 \mu\text{g/mL}$, respectively, compared to the branches with tyrosinase monophenolase inhibition IC_{50} of 268 ± 24 and $91 \pm 8 \mu\text{g/mL}$ in a tyrosinase diphenolase assay. Similar results were found in the antioxidant assays, as leaves exhibited great DPPH and ABTS radical scavenging activities with IC_{50} values of 78 ± 13 and $117 \pm 16 \mu\text{g/mL}$, respectively. Branch extracts showed relatively high IC_{50} values in the DPPH assay ($274 \pm 28 \mu\text{g/mL}$) and ABTS assay ($230 \pm 30 \mu\text{g/mL}$). In contrast, the IC_{50} values of the positive control, Vitamin C, were 72.9 ± 0.5 and $74 \pm 9 \mu\text{g/mL}$ in DPPH and ABTS assays, respectively. Interestingly, the branch extract showed a lower IC_{50} value in the FRAP assay ($3.6 \pm 0.4 \mu\text{g/mL}$) compared to leaves with an IC_{50} value of $4.7 \pm 0.5 \mu\text{g/mL}$.³⁷

4.16. *Citrus junos*. Based on the studies by Adhikari et al., 1000 $\mu\text{g/mL}$ of *Citrus junos* callus extract showed a $59.3 \pm 4.20\%$ inhibition of melanogenesis in B16F10 melanoma cells, which was stronger than the positive control, arbutin.³⁸ The callus extract was also reported to inhibit mushroom tyrosinase activity in a dose-dependent manner. In view of the DPPH assay, 1000 $\mu\text{g/mL}$ of callus extract exhibited $68.5 \pm 9.49\%$ of DPPH free radical scavenging ability, which was comparable to 125 μM of ascorbic acid ($62.3 \pm 1.78\%$).³⁸

4.17. *Clausena indica*. Quan et al. explored the antityrosinase and antioxidant activities of *Clausena indica* root extract by using tyrosinase inhibitory assay and DPPH, ABTS, and lipid peroxidation inhibitory (LPI) assays.³⁹ Among the isolated active components, the *C. indica* roots, clausine K and fraction Re4, performed the most remarkable tyrosinase inhibition, with IC_{50} values of 179.5 and 243.8 $\mu\text{g/mL}$, respectively, stronger than the positive control, myricetin (735.6 $\mu\text{g/mL}$). For the antiradical activities against DPPH and ABTS, nordentatin showed the lowest IC_{50} values of 49.2 ± 0.5 and $69.9 \pm 1.1 \mu\text{g/mL}$, respectively, among other isolates and comparable to the BHT standard (DPPH: $16.0 \pm 0.2 \mu\text{g/mL}$; ABTS: $82.8 \pm 1.1 \mu\text{g/mL}$). Markedly, relatively high IC_{50} values were found in clausine K against DPPH and ABTS, with values of 2197.8 ± 53.3 and $5264.0 \pm 164.0 \mu\text{g/mL}$, respectively. Similarly, in the LPI assay, nordentatin also showed the highest LPI value with $69.8 \pm 0.4\%$, compared to dentatin ($37.9 \pm 0.8\%$) and clausine K ($60.6 \pm 1.1\%$). The BHT showed $82.7 \pm 0.3\%$ inhibition as standard in the LPI assay.³⁹

4.18. *Cosmos caudatus* Kunth. Azwanida et al. reported the antityrosinase and antioxidant activities of *Cosmos caudatus* Kunth leaf extract by using an antityrosinase assay and DPPH and ABTS assays.⁴⁰ The extract showed an IC_{50} value of 693.2 $\mu\text{g/mL}$ for tyrosinase inhibition, while the positive control, kojic acid, showed a value of 77.8 $\mu\text{g/mL}$. In the DPPH and ABTS assays, the extract was reported with IC_{50} values of 163.6 and 57.2 $\mu\text{g/mL}$, respectively. By contrast, the IC_{50} values of the antioxidant activity for the standard used, Trolox, were 3.32 and 6.51 $\mu\text{g/mL}$, respectively.⁴⁰

4.19. *Cymbidium* sp. (Orchidaceae). Axiotis et al. studied the antityrosinase, antioxidant, and collagenase inhibitory activities of all the *Cymbidium* sp. byproduct extracts.⁴¹ From the results obtained, the pseudobulbs' ethanol/water extract presented the highest antityrosinase activity among other extracts, showing $64.11 \pm 2.34\%$ inhibition at 300 $\mu\text{g/mL}$. For the ethyl acetate extracts, flowers, pseudobulbs, and roots exhibited a dose-dependent inhibition of $28.29 \pm 2.93\%$, $37.50 \pm 2.54\%$, and $54.19 \pm 3.72\%$ at 300 $\mu\text{g/mL}$, respectively. In the DPPH assay, ethyl acetate extracts of pseudobulbs and roots exhibited moderate antiradical activity with IC_{50} values of 114.18 and 127.17 $\mu\text{g/mL}$, respectively. However, the dichloromethane (DCM) and ethanol/water extracts of pseudobulbs ($\text{IC}_{50} = 165.78$ and 233.32 $\mu\text{g/mL}$, respectively) and roots ($\text{IC}_{50} = 174.61$ and 304.02 $\mu\text{g/mL}$, respectively) showed weak antioxidant activity. Regarding the collagenase inhibitory test, ethyl acetate extracts of pseudobulbs and roots exhibited high inhibitory activity by displaying $4.01 \pm 1.32\%$ and $82.79 \pm 1.60\%$ inhibition of collagenase at 75 $\mu\text{g/mL}$.⁴¹

4.20. *Cytinus hypocistis*. According to Silva et al., the antityrosinase, antioxidant, and anti-inflammatory activities of *Cytinus hypocistis* whole plants, petals, stalks, and nectar extracts were evaluated.⁴² The highest tyrosinase inhibitory activity was found in *Cytinus hypocistis* stalk extracts, with an IC_{50} value of $0.09 \pm 0.02 \text{ mg/mL}$, followed by a petal extract ($0.19 \pm 0.01 \text{ mg/mL}$), whole plant extract ($0.20 \pm 0.01 \text{ mg/mL}$), and nectar extract ($27.6 \pm 0.7 \text{ mg/mL}$), comparable to the positive control, kojic acid ($0.078 \pm 0.001 \text{ mg/mL}$). Interestingly, in the oxidative hemolysis inhibition assay and thiobarbituric acid reactive substance assay, petal extract exhibited the highest antioxidant activity among other tested extracts, with the IC_{50} value of 279 ± 5 and $342 \pm 2 \text{ ng/mL}$, respectively. In the anti-inflammatory studies, petals and stalk extracts showed similar nitric oxide production inhibitory effects, with IC_{50} values of 127 ± 8 and $127 \pm 12 \mu\text{g/mL}$, respectively. While the IC_{50} values of the whole plant extract and nectar extract were 136 ± 11 and $277 \pm 14 \mu\text{g/mL}$, respectively. The positive control in this assay, dexamethasone, was reported with an IC_{50} of $16 \pm 1 \mu\text{g/mL}$.⁴²

4.21. *Dalea pazensis* Rusby. Santi et al. reported the antimelanogenesis and antityrosinase activities of *Dalea pazensis* Rusby root extract by using the melanin content assay of B16 murine melanoma cells and mushroom tyrosinase assay and intracellular tyrosinase inhibition assay in B16 cells.⁴³ The isolated compound 1 from *Dalea pazensis* Rusby root extracts showed the lowest melanin inhibition IC_{50} of $0.75 \pm 0.2 \mu\text{M}$, followed by compounds 4 ($1.0 \pm 0.4 \mu\text{M}$), 2 ($5.0 \pm 1.0 \mu\text{M}$), and 3 ($5.0 \pm 1.8 \mu\text{M}$). In the mushroom tyrosinase activity assay, the lowest IC_{50} was reported in compound 4 ($2.32 \pm 0.06 \mu\text{M}$), comparable to kojic acid ($4.93 \pm 0.01 \mu\text{M}$), while the highest IC_{50} was found in compound 3 ($49.80 \pm 0.09 \mu\text{M}$). The IC_{50} values of both compounds 1 and 2 were not determined in this assay. However, in the intracellular tyrosinase inhibitory assay, compounds 1, 2, and 3 were found to have 0% inhibition, while compound 4 was reported with $34.2 \pm 0.2\%$ tyrosinase inhibition in B16 cells. The positive control used was kojic acid, with $45.4 \pm 0.1\%$ inhibitory activity reported.⁴³

4.22. *Dendropanax morbiferus* H. Lev. Park et al. revealed the antimelanogenesis and antityrosinase activities of *Dendropanax morbiferus* H. Lev leaf extracts by using melanin content assay and intracellular tyrosinase activity assay in B16F10 melanoma cells.⁸ Water extract of *Dendropanax morbiferus* H. Lev leaves was reported to effectively decrease

the melanin content in α -MSH-stimulated B16F10 cells. Furthermore, the extract also remarkably reduced the intracellular tyrosinase activity in α -MSH-stimulated B16F10 cells in a dose-dependent manner.⁸

4.23. *Dimocarpus longan* Lour. (Longan). Based on Chai et al., the antimelanogenesis and antityrosinase activities of longan bark extract were studied by using the melanin content assay, monophenolase and diphenolase activity assay, and intracellular tyrosinase activity assay using B16 mouse melanoma cells.⁴⁴ The 200 μ g/mL of condensed tannins from longan bark extract reportedly decreased the melanin content of B16 cells to $45.2 \pm 1.3\%$. The IC_{50} values of the condensed tannins reported in the monophenolase activity assay were 43.7 ± 0.3 and 11.5 ± 0.8 μ g/mL in the diphenolase activity assay. Besides, 200 μ g/mL of condensed tannins significantly reduced the intracellular tyrosinase activity of B16 cells to $40.3 \pm 1.5\%$.⁴⁴

4.24. *Erica arborea* L. Zengin et al. explored the antityrosinase and antioxidant activities of *Erica arborea* L. leaf extracts from different extraction methods.⁴⁵ From the mushroom tyrosinase assay, the microwave-assisted extraction (MAE) extract showed the strongest inhibitory activity against the tyrosinase enzyme at 180.29 ± 1.87 mg KAE/g, followed by accelerated solvent extraction (ASE) extract (177.43 ± 2.30 mg KAE/g), Soxhlet (SOE) extract (172.20 ± 1.82 mg KAE/g), maceration (MAC) extract (171.18 ± 3.45 mg KAE/g), and ultrasound-assisted extraction (UAE) extract (171.05 ± 1.14 mg KAE/g). The DPPH scavenging activities of the extracts were in the order of ASE (209.59 ± 4.37 mg TE/g extract) > MAE (179.17 ± 2.93 mg TE/g extract) > MAC (92.19 ± 1.46 mg TE/g extract) > SOE (76.43 ± 0.90 mg TE/g extract) > UAE (66.61 ± 3.41 mg TE/g extract). The same order was also found in the CUPRAC and FRAP assays. A slightly different trend was obtained from the results of the ABTS assay (mg TE/g extract) and phosphomolybdenum (PM) method (mmol TE/g extract), as the extracts were in the order of ASE (ABTS = 359.45 ± 18.22 ; PM = 148.06 ± 1.96) > MAE (325.87 ± 9.48 ; PM = 1.66 ± 0.04) > SOE (185.15 ± 6.28 ; PM = 1.66 ± 0.05) > MAC (176.27 ± 9.25 ; PM = 1.50 ± 0.05) > UAE (148.06 ± 1.96 ; PM = 1.26 ± 0.03). In contrast to the other antioxidant assays, the chelating activity of the extracts was in the order of UAE (5.13 ± 0.42 mg EDTAE/g extract) > ASE (4.74 ± 0.30 mg EDTAE/g extract) > MAC (3.80 ± 0.16 mg EDTAE/g extract) > MAE (3.49 ± 0.40 mg EDTAE/g extract) > SOE (1.43 ± 0.01 mg EDTAE/g extract).⁴⁵

4.25. *Fagus sylvatica* L. Tanase et al. reported that the 50:50 ethanol–water extract of *Fagus sylvatica* L. has the strongest antioxidant activity in DPPH (741.43 ± 59.44 mg TE/g extract) and FRAP (783.24 ± 31.24 mg TE/g extract) assays, where this extract was recorded with the highest total phenolic contents.⁴⁶ The authors stated that antioxidant activity was also strongly associated with the amount of phenolic compounds. Besides, water extract showed higher antioxidant activities in both DPPH and FRAP assays (DPPH = 676.29 ± 19.80 ; FRAP = 783.24 ± 31.24 mg TE/g extract), as compared to the 80:20 ethanol–water extract (DPPH = 505.02 ± 42.02 ; FRAP = 592.84 ± 44.02 mg TE/g extract). On the other hand, the 50:50 ethanol–water extract of *Fagus sylvatica* L. bark was reported with $45.99 \pm 5.26\%$ tyrosinase inhibitory activity in mushroom tyrosinase activity assay using L-DOPA as a substrate, while water extract and 80:20 ethanol–water extract did not show any tyrosinase inhibitory activity.⁴⁶

4.26. *Feijoa sellowiana*. The antityrosinase and antioxidant activities of *Feijoa sellowiana* leaf extract were reported by Saber et al.⁴⁷ The mushroom tyrosinase inhibition of the methylene chloride extract was 115.85 ± 2.55 mg of KAE/g of extract, while the quercetin (positive control) was 163.05 ± 5.19 mg of KAE/g extract. To evaluate the antioxidant activity of the extract, a total of 6 assays were done, which were DPPH (90.58 ± 0.89 mg TE/g extract), ABTS (113.80 ± 0.02 mg TE/g extract), FRAP (102.58 ± 0.41 mg TE/g extract), CUPRAC (180.23 ± 0.44 mg TE/g extract), metal chelating (21.21 ± 0.88 mg EDTAE/g extract), and PM (5.31 ± 0.13 mg TE/g extract) assays.⁴⁷

4.27. *Galla rhois*. According to Parvez et al., the tyrosinase inhibition IC_{50} of *Galla rhois* methanol extract was reported at 0.163 mg/mL, lower than that for kojic acid (0.316 mg/mL), ascorbic acid (1.520 mg/mL), and arbutin (2.511 mg/mL) in the mushroom tyrosinase activity assay using L-DOPA as a substrate.⁴⁸

4.28. *Garcinia atroviridis*. According to a study done by Chatatikun et al. that investigated the antimelanogenesis properties of various concentrations of water extracts of *Garcinia atroviridis*, the melanin content of α -MSH-stimulated B16F10 cells was decreased in a concentration-dependent manner.⁴⁹ At 125 μ g/mL (maximum concentration tested) of water extract, it reduced the melanin content to 46.96% which was comparable to that of kojic acid (46.94%). In mushroom tyrosinase activity assay, water extract showed IC_{50} of 40.72 ± 1.83 μ g/mL, while kojic acid was 8.00 ± 0.47 μ g/mL. Nevertheless, only a concentration of 125 μ g/mL of water extract was found to effectively inhibit the cellular tyrosinase activity in B16F10 cells. The DPPH and ABTS radical scavenging activities of water extract were reported with IC_{50} values of 628.85 ± 32.67 μ g/mL and 321.41 ± 12.76 μ g/mL, respectively, while ascorbic acid was used as the positive control (DPPH = 62.22 ± 0.67 ; ABTS = 6.27 ± 0.19 μ g/mL).⁴⁹

4.29. *Gentiana veitchiorum*. Based on Wu et al., the flower extracts of *Gentiana veitchiorum* reported greatly reduced the melanin content on B16F10 cells, but the root extract did not show any antimelanogenesis effect.⁵⁰ Isoorientin was identified from the flower extract, which decreased the melanin content in a dose-dependent manner. Isoorientin was also found to inhibit intracellular tyrosinase activity in a dose-dependent manner but did not have a significant inhibitory effect on mushroom tyrosinase activity. As for antioxidant assay, the flower extracts and isoorientin showed significantly reduced cellular reactive oxygen species (ROS) levels.⁵⁰

4.30. Granny Smith Apple. Menbari et al. reported the antityrosinase activity of Granny Smith culture cell extract in a mushroom tyrosinase activity assay using L-DOPA as a substrate. The IC_{50} of the extract was 1.21 mg/mL, while that for kojic acid was reported to be 0.0177 mg/mL.⁵¹

4.31. *Hippophae rhamnoides* L. Zhang et al. explored the antimelanogenesis, antityrosinase, and antioxidant activities of *Hippophae rhamnoides* L. seed residues extracted by 80% ethanol.¹² The results showed that the seed residue extract (4.55 and 45.45 mg mL⁻¹) effectively reduced the melanin content in B16F10 mouse melanoma cells. Besides, the seed residue extract (concentration ranging from 0.10 to 3.00 mg mL⁻¹) significantly reduced the tyrosinase activity in B16F10 cells compared to the control, kojic acid. In the DPPH assay, an EC_{50} of 0.09 ± 0.01 mg mL⁻¹ was reported in seed residue extract, comparable to the positive standards of ascorbic acid (0.25 ± 0.02 mg mL⁻¹) and Trolox (0.10 ± 0.00 mg mL⁻¹).

Nevertheless, the seed residue extract showed little hydroxyl scavenging ability.¹²

4.32. *Juglans mandshurica*. Based on Kim et al., *Juglans mandshurica* fruit methanol extract showed antimelanogenesis effects in B16F10 melanoma cells by significantly reducing the expression of the melanocyte-inducing transcription factor (MITF). The isolated compound 1 showed the strongest antimelanogenesis effects by effectively decreasing the expression of MITF and decreasing melanin content in a dose-dependent manner. On the other hand, compound 1 showed strong tyrosinase inhibition activity by decreasing tyrosinase expression in the tyrosinase activity assay using L-DOPA as a substrate.⁵²

4.33. *Kadsura coccinea*. Jeon et al. explored the antioxidant activity of different plant parts of *Kadsura coccinea* extract and showed that leaves had the highest DPPH and ABTS radical scavenging activity (DPPH = $99.9 \pm 0.1\%$; ABTS = $94.7 \pm 2.9\%$) followed by roots (DPPH = $95.5 \pm 3.6\%$; ABTS = $82.8 \pm 5.9\%$), seeds (DPPH = $25.7 \pm 2.1\%$; ABTS = $29.7 \pm 2.0\%$), and flowers (DPPH = $8.7 \pm 1.1\%$; ABTS = $15.9 \pm 2.0\%$).⁵³ The authors highlighted that the leaves and root extracts had high polyphenol contents. In view of the melanin content assay using α -MSH-stimulated B16F10 murine melanoma cells, the antimelanogenesis activities of the extracts were in the order of leaves > roots > stems > fruits. A similar trend was observed in the antityrosinase assay, and the extracts also followed the order of leaves > roots > stems > fruits in terms of the extracts' antityrosinase properties.⁵³

4.34. *Kummerowia striata*. Lee et al. reported the antimelanogenesis, antityrosinase, and antioxidant activities of *Kummerowia striata* aerial parts of ethanol extract. The extract was found to decrease the melanin content in α -MSH-stimulated B16F10 cells in a dose-dependent manner in the melanin content assay.⁵⁴ Similar to the mushroom tyrosinase activity assay, the extract also exerted significant tyrosinase inhibitory activity in a dose-dependent manner. The DPPH and ABTS assays revealed that the radical scavenging activities of the extract, IC₅₀ values of $98.71 \mu\text{g/mL}$ and $24.64 \mu\text{g/mL}$, respectively, were reported. The beta hydroxyl acid (BHA) was used as the standard control in both antioxidant assays, with the IC₅₀ of $14.96 \mu\text{g/mL}$ (DPPH) and $4.65 \mu\text{g/mL}$ (ABTS).⁵⁴

4.35. *Leonurus japonicus*. Lai et al. studied the methanol extract of *Leonurus japonicus* aerial parts in a melanin content assay and cellular tyrosinase activity assay using B16F10 murine melanoma cells. Five diterpenes identified from the extracts were reported to inhibit melanin production in α -MSH-stimulated B16F10 cells, while two diterpenes from the extracts had moderate antityrosinase activity.⁵⁵

4.36. *Lepechinia meyenii*. Crespo et al. examined the antityrosinase activity of *Lepechinia meyenii* by subjecting the extracts to bioguided fractionation to isolate three bioactive compounds (*p*-coumaric acid, caffeic acid, and rosmarinic acid).⁵⁶ These three compounds were shown to be highly effective in inhibiting tyrosinase activity and to be more powerful than kojic acid. *p*-Coumaric acid had the strongest antityrosinase effects among the three compounds (IC₅₀ using L-tyrosine as a substrate: $0.30 \mu\text{M}$; IC₅₀ using L-DOPA as a substrate: $0.62 \mu\text{M}$). Based on previous research, *p*-coumaric acid was shown to have an efficient antimelanogenesis activity and strong free radical scavenging ability. It was also known as an effective tyrosinase inhibitor due to having a similar structure to the tyrosinase substrate and competing for the active sites with the substrate on tyrosinase.⁵¹ The authors concluded that the fractions and isolated compounds,

especially *p*-coumaric acid, could be used as a depigmenting agent.

4.37. *Limonium delicatulum*. Bakhouch et al. examined the antityrosinase, antioxidant, and anti-inflammatory activities of *Limonium delicatulum* leaves and root extracts by using methanol and water.⁵⁷ The results showed that methanol extract from roots strongly inhibited the enzyme with an IC₅₀ value of $9.87 \pm 0.15 \mu\text{g/mL}$ and was more potent than methanol extract from leaves ($24.77 \pm 0.5 \mu\text{g/mL}$) and kojic acid ($25.23 \pm 0.21 \mu\text{g/mL}$). All of the water extracts did not show any effects in the tyrosinase inhibition assay. The DPPH assay was used to measure the scavenging activity of the extracts, and the results showed that methanol root extract (IC₅₀ = $5.79 \pm 0.05 \mu\text{g/mL}$) was the most powerful followed by methanol leaf extract (IC₅₀ = $10.58 \pm 0.18 \mu\text{g/mL}$). Furthermore, methanol leaves and roots extracts of *L. delicatulum* exhibited higher antioxidant activity than BHT (IC₅₀ = $16.02 \pm 0.35 \mu\text{g/mL}$). The aqueous extracts also exerted good antiradical activity, as the IC₅₀ values obtained for aqueous roots and leaf extracts were 69.34 ± 0.95 and $79.65 \pm 0.23 \mu\text{g/mL}$, respectively. In a galvinoxyl radical (GOR) assay, results showed that methanol root extract exhibited a slightly higher antioxidant activity than methanol leaf extract (IC₅₀ = 10.31 ± 0.82 and $11.09 \pm 0.16 \mu\text{g/mL}$, respectively), while methanol extracts from leaves and roots exhibited a close trapping effect on the ABTS radical (IC₅₀ = 6.56 ± 0.25 and $7.29 \pm 0.04 \mu\text{g/mL}$, respectively), which is better than BHT ($7.54 \pm 0.69 \mu\text{g/mL}$) and aqueous roots and leaf extracts (IC₅₀ = 29.16 ± 0.16 and $26.01 \pm 0.93 \mu\text{g/mL}$, respectively). The IC₅₀ values of aqueous root and leaf extracts against galvinoxyl radicals were 50.17 ± 2.09 and $84.07 \pm 0.44 \mu\text{g/mL}$, respectively. In the CUPRAC assay, methanol roots extract presented an A_{0.5} of $6.81 \pm 0.07 \mu\text{g/mL}$ and were stronger than ascorbic acid and Trolox (A_{0.5} = 8.69 ± 0.14 and $8.31 \pm 0.15 \mu\text{g/mL}$, respectively). Similarly, methanol extract from leaves gave a promising effect to reduce copper ions with an A_{0.5} of $13.5 \pm 0.55 \mu\text{g/mL}$, while aqueous extracts exhibited the weakest reducing capacity. Methanol leaf extract displayed higher reducing power when compared to methanol roots extract (A_{0.5} = 11.2 ± 0.06 and $20.51 \pm 0.3 \mu\text{g/mL}$, respectively), whereas aqueous roots extract exhibited a higher effect than leaf extract with A_{0.5} values of 46.54 ± 0.4 and $95.57 \pm 2.02 \mu\text{g/mL}$, respectively. Methanol leaf extract presented an A_{0.5} of $9.45 \pm 0.9 \mu\text{g/mL}$ and showed a better antioxidant capacity than methanolic roots extract and Trolox (21.66 ± 0.08 and $34.17 \pm 1.23 \mu\text{g/mL}$, respectively). Besides, in phenanthroline metal iron-reduction analysis, the lowest value of A_{0.5} was obtained with methanol roots extract ($3.55 \pm 0.02 \mu\text{g/mL}$), followed by methanol leaf extract ($7.34 \pm 0.27 \mu\text{g/mL}$), aqueous roots extract ($11.82 \pm 0.75 \mu\text{g/mL}$), and aqueous leaf extract ($22.6 \pm 1.36 \mu\text{g/mL}$), respectively. In silver nanoparticle assay (SNP), methanol leaf extract showed the highest potential to reduce silver ions (Ag⁺) than other extracts, with the A_{0.5} of $9.45 \pm 0.9 \mu\text{g/mL}$ which was comparable to the ascorbic acid ($7.14 \pm 0.05 \mu\text{g/mL}$) and Trolox ($34.17 \pm 1.23 \mu\text{g/mL}$). Lastly, methanol leaf extract exhibited slight activity with an IC₅₀ value of $98.6 \pm 0.32 \mu\text{g/mL}$, while aqueous leaf extract showed a very weak effect with an IC₅₀ of $293.17 \pm 0.14 \mu\text{g/mL}$ in the β -Carotene-linoleic acid bleaching assay. The anti-inflammatory analysis showed that methanol leaf extract exhibited the highest inhibition activity of $90.21 \pm 1.69\%$ at $500 \mu\text{g/mL}$, followed by methanol roots extract ($89.74 \pm 1.63\%$), aqueous leaf

extract ($43.32 \pm 0.13\%$), and last aqueous roots extract ($38.14 \pm 0.81\%$).⁵⁷

4.38. *Lophira lanceolata* Tiegh. ex Keay. Sinan et al. reported the antityrosinase and antioxidant activities of *lanceolata* leaf and stem bark extracts by using colorimetric enzyme inhibition assay and DPPH, ABTS, CUPRAC, FRAP, and ferrous-ion chelating assays.⁵⁸ The antityrosinase effects were exhibited for the methanol leaf extracts, with the highest activity reported for extract obtained using the Soxhlet extraction method (131.17 ± 1.96 mg KAE/g), followed by HAE-MeOH (126.03 ± 3.57 mg KAE/g) and MAC-MeOH (122.21 ± 2.79 mg KAE/g). No inhibitory activity against tyrosinase was displayed by the HAE-Water and MAC-Water extracts. All stem bark extracts showed significant inhibitory potency against tyrosinase in the following order: MAC-MeOH (153.21 ± 0.15 mg KAE/g) > SOX-MeOH (151.98 ± 0.66 mg KAE/g) > HAE-MeOH (151.65 ± 0.25 mg KAE/g) > infusion (100.95 ± 2.37 mg KAE/g) > MAC-water (100.46 ± 2.27 mg KAE/g) > HAE-Water (94.58 ± 1.87 mg KAE/g).⁵⁸ For the leaf extracts, the highest free scavenging activity was observed in the HAE-MeOH (DPPH = 93.82 ± 0.23 ; ABTS = 132.25 ± 0.09 mg TE/g), followed by infused (DPPH = 93.81 ± 0.43 mg TE/g) and SOX-MeOH (ABTS = 132.09 ± 0.07 mg TE/g) extracts (58). The HAE-MeOH extract has shown the highest cupric and ferric reducing power, with values of 287.73 ± 21.98 and 231.21 ± 0.57 mg TE/g, respectively. Among the stem bark extracts, the highest free radical quenching activity was exhibited by the SOX-MeOH (DPPH = 195.18 ± 0.55 ; ABTS = 265.04 ± 0.99 mg TE/g), followed by HAE-MeOH (DPPH: 194.83 ± 0.21 ; ABTS = 264.43 ± 0.13 mg TE/g) extracts. Furthermore, reducing capacity was exhibited by all the tested stem bark extracts, with the aqueous extracts obtained using maceration (CUPRAC = 853.99 ± 13.27 ; FRAP = 853.99 ± 13.27 mg TE/g) and homogenizer assisted (CUPRAC = 683.57 ± 11.09 ; FRAP = 648.34 ± 3.86 mg TE/g) methods being superior sources of reducing agents in both CUPRAC and FRAP assay. With respect to metal chelating properties, the activity varied between 6.76 ± 1.76 (HAE-Water) and 22.68 ± 0.74 (HAE-MeOH) mg EDTAE/g and 2.09 ± 0.45 (MAC-MeOH) and 6.15 ± 1.12 mg EDTAE/g for the leaf and stem bark extracts, respectively.⁵⁸

4.39. *Lotus*. The lotus seedpod was extracted with hot water (95°C) with concentrations of 0, 5, 10, 15, and 20 $\mu\text{g/mL}$, and the antimelanogenesis and antityrosinase activities were studied by Hsu et al. The concentrations of 10, 15, and 20 $\mu\text{g/mL}$ of the seedpod extract of lotus greatly reduced the melanin production in α -MSH-stimulated B16F10 cells, showing the promising antimelanogenesis properties of the extracts. Similarly, the concentrations of 10, 15, and 20 $\mu\text{g/mL}$ of the seedpod extract of lotus significantly decreased the 65%, 76%, and 112% of tyrosinase activity in α -MSH-stimulated B16F10 cells.⁵⁹

4.40. *Maclura tricuspidate*. Jo et al. examined the antityrosinase and antioxidant activities of the leaf extract of *Maclura tricuspidate* by using the mushroom tyrosinase activity assay and DPPH assay. Results showed that the two identified flavanols named kaempferol and quercetin had the most potent activity for tyrosinase inhibition and also exhibited good antioxidant activity.⁶⁰

4.41. *Manilkara kauki*. Based on Srisupap and Chaicharoenpong, the methanol extract of *Manilkara kauki* stem barks showed the lowest IC_{50} value of tyrosinase inhibition,

0.25 ± 0.03 mg/mL, followed by water extract of *Manilkara kauki* stem barks, 0.41 ± 0.01 mg/mL.¹⁵ Overall, methanol extracts showed a lower IC_{50} of tyrosinase inhibition compared with the water extracts. The same tyrosinase inhibitory trend was found in both extraction methods, which followed the order of stem barks > leaves > seeds, while woods showed no inhibitory activity at all. In the DPPH assay, methanol extract of stem barks showed the highest radical scavenging activity of $57.87 \pm 0.27\%$, followed by water extract of leaves ($55.49 \pm 0.06\%$), methanol extract of leaves ($47.01 \pm 0.14\%$), and methanol extract of woods ($43.51 \pm 0.27\%$) (15). On the other hand, the methanol extract of stem barks also exhibited the strongest FRAP activity with 211.59 ± 1.40 mg TE g^{-1} crude extract, followed by water extract of leaves, with 219.37 ± 0.32 mg TE g^{-1} crude extract.¹⁵

4.42. *Melaleuca quinquenervia*. Chao et al. revealed that the 20 $\mu\text{g/mL}$ of *Melaleuca quinquenervia* essential oil exhibited a 40.7% melanin inhibitory effect, stronger than the positive control, arbutin (16.1% at 100 μM), in the melanin content assay using B16 murine melanoma cells.¹ Furthermore, the 20 $\mu\text{g/mL}$ of essential oil had a 20.4% tyrosinase inhibitory effect, which is stronger than arbutin (5.5% at 100 μM).¹

4.43. *Melastoma normale*. Quercetin, one of the compounds that was isolated from *Melastoma normale* roots' 80% acetone extract, showed significant antityrosinase activity with IC_{50} of 76.83 ± 2.02 μM , while kojic acid has an IC_{50} of 100.52 ± 2.63 μM , reported by He et al.⁶¹

4.44. *Morus alba* L. Li et al. were the first to report the antimelanogenesis and antityrosinase activity of *Morus alba* L. leaf extract. The three compounds isolated from ethanol extracts named, norartocarpetin, moracin J and steppogenin decreased melanin production which exhibited antimelanogenesis effects in α -MSH-stimulated B16F10 cells.⁵ The antityrosinase activity of *Morus alba* L. leaf extract was shown in norartocarpetin, moracin J and steppogenin significantly inhibited mushroom tyrosinase activity and intracellular tyrosinase activity in a dose-dependent manner in B16F10 cells.⁵ Another study by Chaiyana et al. explored the antityrosinase and antioxidant activities of the maceration method and pulsed electric field (PEF) extraction method of *Morus alba* L. leaves obtained from Chiang Mai (CM), Sakon Nakhon (SK), Buriram (BR), Thailand. Results showed that PEF extracts exhibited significant inhibitory effects compared to the maceration method, while PEF extract from BR demonstrated the highest antityrosinase activity, with IC_{50} against L-tyrosine and L-DOPA of 54.1 ± 5.4 and 32.2 ± 3.4 $\mu\text{g/mL}$, respectively. These results were comparable to kojic acid ($\text{IC}_{50} = 28.0 \pm 5.1$ $\mu\text{g/mL}$ with L-DOPA as substrate), the positive control. Expectedly, extracts obtained by the PEF method had higher radical scavenging activity than the maceration method, and leaves from BR had a significantly high FRAP value. To be specific, PEF extract from BR had DPPH inhibition of $45.3 \pm 0.8\%$, TEAC value of 115.1 ± 2.8 mg Trolox/g extract (ABTS assay), and EC_1 value of 52.4 ± 0.5 mg FeSO_4/g extract (FRAP assay).⁶²

4.45. *Myrica rubra*. Juang et al. examined the antimelanogenesis and antityrosinase properties of *Myrica rubra* fruit extract with different solvent extraction.⁶ Results published suggested that pure water extract has stronger melanogenesis inhibitory effects than 50% ethyl alcohol and 95% ethyl alcohol extracts, as 2.0 g L^{-1} of pure water extract reduced the melanin content to 76.5% and 82.5% in A2058 and B16F10 mouse melanoma cells, respectively. Interestingly, pure water extract

also has stronger tyrosinase inhibitory effects than 50% ethyl alcohol and 95% ethyl alcohol extracts. The 2.0 g L⁻¹ of pure water extract successfully reduced the mushroom tyrosinase activity to 61.7% and reduced the cellular tyrosinase activity to 65.78% and 74.9% in A2058 and B16F10 cells, respectively.⁶

4.46. *Nardostachys jatamansi*. Bose et al. found that methanol rootstock extracts of *in vitro*-cultured *Nardostachys jatamansi* plants have the highest antityrosinase activity with IC₅₀ of 168.12 ± 3.6 μg/mL, which is comparable to kojic acid 54.44 ± 2.3 μg/mL.⁶³ The antioxidant potential of methanol rootstock extracts of *in vitro*-cultured plants was demonstrated in ABTS and PM assays, as well as the lipid peroxidation (LPO) inhibition method. The IC₅₀ of methanol rootstock extracts was 13.55 ± 0.8 μg/mL in the ABTS assay and 789 ± 8.7 μg ascorbic acid equivalents/g extract in the PM assay. While the result obtained from the LPO inhibition method was 15.24 ± 0.8 μg/mL for the methanol rootstock extracts of *in vitro*-cultured plants and 3.82 ± 0.5 μg/mL reference value of rutin. Lastly, the methanol rootstock extracts of *in vitro*-cultured plants showed 14.58 ± 0.9 μg/mL anti-inflammatory activity, which was stronger than the methanol leaf extracts of *in vitro*-cultured plants with IC₅₀ of 23.54 ± 1.6 μg/mL.⁶³

4.47. *Nepeta glomerulosa* Boiss. Emami et al. evaluated the antimelanogenesis inhibitory activity of methanol (MeOH), *n*-hexane, ethyl acetate (EtOAc), dichloromethane (CH₂Cl₂), *n*-butanol (BuOH), and water extracts isolated from *N. glomerulosa* in B16 melanoma cell line.³ From the results obtained, a 100 μg/mL concentration of MeOH, EtOAc and *n*-BuOH extracts showed significant inhibitory effects on melanin synthesis. However, mushroom tyrosinase activity was inhibited only by 100 μg/mL of EtOAc extract, while 100 μg/mL of methanol extract significantly inhibited cellular tyrosinase activity in B16F10 cells. Only MeOH and *n*-BuOH extracts greatly suppressed the oxidative stress caused by hydrogen peroxide in the B16F10 melanoma cells.³

4.48. *Olea europaea*. Elkattan et al. explored the anti-melanogenesis activity of *Olea europaea* leaf extract, and three compounds named oleuropein, oleoside dimethyl ester, and oleoside 11-methyl ester presented good inhibition of melanogenesis in B16 melanoma cells.⁶⁴ In particular, the melanin content of oleuropein at 12.5, 25, and 50 μM was 63.8 ± 3.3%, 46.4 ± 3.3%, and 33.9 ± 15.4%, respectively, while those of oleoside dimethyl ester were 33.9 ± 4.0% (12.5 μM), 28.1 ± 0.7% (25 μM), and 5.3 ± 3.8% (50 μM). Those of oleoside 11-methyl ester were 25.8 ± 8.1% (12.5 μM), 22.3 ± 14.0% (25 μM), and 16.0 ± 10.2% (50 μM).⁶⁴ For reference, the melanin content of arbutin at 20 μM was 91.3 ± 2.6%.⁶⁴

4.49. *Pelargonium graveolens*. Aanachi et al. explored the antityrosinase activity of *Pelargonium graveolens* using *n*-hexane, dichloromethane, and methanol as solvent extraction.⁶⁵ The result demonstrated that methanol extract exhibited the strongest antityrosinase activity among the 3 extracts with IC₅₀ of 21.11 ± 0.38 μg/mL. The tyrosinase inhibition IC₅₀ of *n*-hexane was 37.60 ± 1.83 μg/mL, while dichloromethane was 37.63 ± 1.35 μg/mL. For reference, kojic acid was reported with an IC₅₀ value of 25.23 ± 0.78 μg/mL in the tyrosinase inhibition assay. The antioxidant capacity of the extracts of *P. graveolens* was evaluated, and the methanol extract was reported to be the strongest in all five assays including the DPPH (IC₅₀ of 12.96 ± 0.63 μg/mL), ABTS (IC₅₀ of 10.20 ± 0.63 μg/mL), CUPRAC (A_{0.5} of 20.29 ± 0.51 μg/mL), iron chelation (IC₅₀ of 31.74 ± 3.21 μg/mL), and reducing power (A_{0.5} of 43.38 ± 0.65 μg/mL). In contrast,

the antioxidant activity of dichloromethane extract was moderate, with IC₅₀ values of 116.91 ± 6.50 μg/mL (DPPH), 10.46 ± 1.33 μg/mL (ABTS), and 66.72 ± 2.96 μg/mL (iron chelation) and A_{0.5} values of 53.36 ± 0.88 and 64.60 ± 0.15 μg/mL for CUPRAC and reducing power, respectively. Generally, the lowest capacity was observed with the hexane extract, with the IC₅₀ of 37.60 ± 1.83, 44.46 ± 2.30, and 47.20 ± 2.85 μg/mL for the DPPH, ABTS, and iron chelation assays and A_{0.5} of 89.95 ± 3.00 and 77.29 ± 0.87 μg/mL in CUPRAC and reducing power.⁶⁵

4.50. *Persicaria orientalis*. Based on Masum et al., vanicoside B isolated from ethanolic extracts of *Persicaria orientalis* roots exhibited a significant high extracellular (71.9% and 72.0%) and intracellular (35.3 and 27.3%) melanin inhibitory activity at 50 and 25 μM, respectively, in the B16 mouse melanoma cells.⁶⁶ It showed better inhibitory activity than the positive control, arbutin (58% at 730 μM).⁶⁶ Furthermore, the ethanolic extract also demonstrated the highest tyrosinase inhibition with IC₅₀ of 22 μg/mL (L-tyrosine) and 39 μg/mL (L-DOPA), compared to the ethyl acetate extract (L-tyrosine = 80 μg/mL; L-DOPA = 311 μg/mL) and *n*-hexane (L-tyrosine = >1000 μg/mL; L-DOPA = >1000 μg/mL).⁶⁶ The kojic acid was used as the positive control in the mushroom tyrosinase assay, with the IC₅₀ of 2 μg/mL (L-tyrosine) and 26 μg/mL (L-DOPA assay) reported.⁶⁶

4.51. *Photinia × fraseri*. Song et al. reported that crude proanthocyanidin (PA) extract of *Photinia × fraseri* leaves demonstrated better inhibition of tyrosinase diphenolase activity than monophenolase activity in the mushroom tyrosinase activity assay.⁶⁷

4.52. *Phyllanthus phyllyreifolius*. Mahomoodally et al. revealed that the macerated ethyl acetate extract of the aerial parts of *P. phyllyreifolius* exhibited the highest tyrosinase inhibitory properties with 88.93 ± 0.53 mg KAE/g followed by macerated methanolic extract (88.46 ± 1.35 mg KAE/g), Soxhlet methanolic extract (87.19 ± 0.28 mg KAE/g), Soxhlet ethyl acetate extract (78.79 ± 1.52 mg KAE/g), and decoction extract (66.29 ± 1.51 mg KAE/g).⁶⁸ Besides, the macerated methanol extract of *P. phyllyreifolius* possessed the highest DPPH and ABTS scavenging properties (2.91 ± 0.01 and 4.12 ± 0.09 mmol TE/g, respectively), while the decoction extract was also equally effective in scavenging the ABTS radical (4.11 ± 0.02 mmol TE/g). The decoction extract was the weakest DPPH scavenger (1.91 ± 0.13 mmol TE/g) (68). In the CUPRA assay, Soxhlet methanolic extract showed the highest activity at 5.04 ± 0.17 mmol TE/g, followed by macerated methanol extract (4.96 ± 0.12 mmol TE/g), decoction extract (4.80 ± 0.07 mmol TE/g), macerated ethyl acetate extract (4.78 ± 0.33 mmol TE/g), and last the Soxhlet ethyl acetate extract (3.75 ± 0.03 mmol TE/g). A similar trend was reported in the metal chelating assay, with the order of Soxhlet methanolic extract > macerated methanol extract > decoction extract > Soxhlet ethyl acetate extract > macerated ethyl acetate extract. Similarly, the Soxhlet methanolic extract also exhibited the highest FRAP activity at 3.17 ± 0.15 mmol TE/g, followed by decoction extract (3.01 ± 0.12 mmol TE/g), macerated methanol extract (2.92 ± 0.36 mmol TE/g), macerated ethyl acetate extract (2.31 ± 0.11 mmol TE/g), and Soxhlet ethyl acetate extract (2.02 ± 0.10 mmol TE/g).⁶⁸

4.53. *Phyllostachys nigravar Henosis*. Choi et al. discovered that the 80% ethanol extracts from the *P. nigravar* bamboo stem decreased the melanin contents in α-MSH-stimulated B16F10 cells in a dose-dependent manner.¹³ The

tyrosinase inhibitory potential of the 80% ethanol extracts was moderate, with an IC_{50} of $243.7 \mu\text{g/mL}$, compared to the ascorbic acid of $38.5 \mu\text{g/mL}$.¹³ Furthermore, the highest DPPH and ABTS scavenging effects were found in the 80% ethanol extracts, with the IC_{50} of 565.63 ± 17.75 and $414.61 \pm 35.12 \mu\text{g/mL}$, respectively, followed by the 50% ethanol extracts (DPPH: 714.35 ± 39.54 ; ABTS: $463.81 \pm 13.93 \mu\text{g/mL}$). The 100% ethanol extracts showed the least DPPH activity, with an IC_{50} of $2019.67 \pm 69.40 \mu\text{g/mL}$, while boiling water extracts showed the least ABTS scavenging effects ($2258.18 \pm 125.06 \mu\text{g/mL}$). In the hydroxyl radical assay, similar results were reported in 50% and 80% ethanol extracts, with an IC_{50} of 560.19 ± 21.85 and $509.17 \pm 33.76 \mu\text{g/mL}$, respectively.¹³ Generally, the antioxidant activity of the extracts followed the order of 80% ethanol extracts > 50% ethanol extracts > 100% ethanol extracts > water > boiling water.

4.54. *Pistacia atlantica* Subsp. *Mutica*. Eghbali-Feriz et al. discovered the *P. atlantica* MeOH, CH_2Cl_2 , and EtOAc extracts (0.2 to $200 \mu\text{g/mL}$), and *n*-hexane (2 to $200 \mu\text{g/mL}$) and H_2O extract (20 and $200 \mu\text{g/mL}$) showed significant inhibitory effect on melanogenesis; however, essential oil and BuOH had no significant inhibitory effect on melanogenesis.¹¹ Besides, all extracts of the *P. atlantica* were reported to inhibit mushroom tyrosinase activity except for $1000 \mu\text{g/mL}$ of *n*-hexane extract. In cellular tyrosinase activity assay, MeOH, EtOAc, and BuOH extracts (0.2 – $200 \mu\text{g/mL}$), *n*-hexane ($0.2 \mu\text{g/mL}$), and CH_2Cl_2 (20 and $200 \mu\text{g/mL}$) were found to effectively inhibit B16F10 cells' tyrosinase activity except for H_2O extract. Lastly, all extracts except $0.2 \mu\text{g/mL}$ of CH_2Cl_2 extract were able to significantly suppress the oxidative stress caused by hydrogen peroxide.¹¹

4.55. *Pistacia lentiscus* L. Elloumi et al. examined the antityrosinase potential of PDL leaf extract in both mushroom tyrosinase activity assay and cellular tyrosinase activity assay in B16 cells.⁶⁹ The ethyl acetate (EAE) extract exhibited a great cellular tyrosinase activity with IC_{50} of $27.85 \pm 1.75 \mu\text{g/mL}$, compared to the kojic acid with IC_{50} of $142.09 \pm 2.72 \mu\text{g/mL}$. However, the EAE extract only showed moderate mushroom tyrosinase activity with IC_{50} of $123 \mu\text{g/mL}$, compared to the kojic acid ($20 \mu\text{g/mL}$). Besides, the EAE extract exhibited the strongest antioxidant activity among the 3 extracts with IC_{50} of $18.07 \mu\text{g/mL}$ in the DPPH assay and $522.76 \pm 22.99 \text{ mg AEAC/g}$ extract in the FRAP assay. Methanolic extract and aqueous extract showed similar antioxidant activity with IC_{50} of 19.62 and $19.52 \mu\text{g/mL}$ in the DPPH assay, respectively, while 467.29 ± 21.77 and $421.91 \pm 15.48 \text{ mg AEAC/g}$ extract were in the FRAP assay, respectively. The reference value from ascorbic acid in the DPPH assay was $13.85 \mu\text{g/mL}$. The antilastase potential of EAE extract was reported with IC_{50} of $19 \mu\text{g/mL}$, which is comparable to the epigallocatechin gallate of $12 \mu\text{g/mL}$.⁶⁹

4.56. *Polygonum maritimum* L. Rodrigues et al. reported that an acetone extract of *P. maritimum* L. was able to effectively reduce nitric acid production on LPS-stimulated RAW 264. Seven macrophages with IC_{50} of $22.0 \mu\text{g/mL}$ were compared to positive control ($27.6 \mu\text{g/mL}$).⁷⁰ The antioxidant activity of acetone extract was evaluated by determining radical scavenging activity on superoxide radicals, ferric thiocyanate, and thiobarbituric acid tests and total antioxidant capacity; results obtained were presented with IC_{50} values of $40.4 \mu\text{g/mL}$, $784 \mu\text{g/mL}$, and $647 \mu\text{g/mL}$, respectively. Nevertheless, the acetone extract tyrosinase inhibitory effect was reported with an

IC_{50} of $64.1 \mu\text{g/mL}$, much lower than the positive control, arbutin, with $137 \mu\text{g/mL}$.⁷⁰

4.57. *Potentilla anserina* L. Based on Yang et al., in the tyrosinase inhibitory assay, the most active fraction from *P. anserina* extract was the butyl alcohol fraction [$IC_{50} = 45.22 \mu\text{g/mL}$ (L-tyrosine), $IC_{50} = 15.47 \mu\text{g/mL}$ (L-DOPA)], which was followed by the ethyl acetate fraction, the total extract, and the aqueous fraction with IC_{50} from 81.40 to $250.95 \mu\text{g/mL}$ (L-tyrosine) and IC_{50} from 33.37 to $128.56 \mu\text{g/mL}$ (L-DOPA), respectively.⁷¹ With regard to the DPPH and ABTS assays, the most active fraction was the ethyl acetate fraction [$IC_{50} = 0.11 \mu\text{g/mL}$ (for DPPH), $IC_{50} = 0.42 \mu\text{g/mL}$ (for ABTS)] followed by the butyl alcohol fraction [$IC_{50} = 1.16 \mu\text{g/mL}$ (for DPPH), $IC_{50} = 4.58 \mu\text{g/mL}$ (for ABTS)], total extract [$IC_{50} = 7.27 \mu\text{g/mL}$ (for DPPH), $IC_{50} = 25.91 \mu\text{g/mL}$ (for ABTS)] and aqueous fraction [$IC_{50} = 16.33 \mu\text{g/mL}$ (for DPPH), $IC_{50} = 60.71 \mu\text{g/mL}$ (for ABTS)]. Notably, the ethyl acetate fraction is presented with the highest FRAP value.⁷¹

4.58. *Potentilla paradoxa* Nutt. Lee et al. revealed that the melanin content of α -MSH-stimulated B16F10 cells was suppressed dose dependently by 95% ethanol extract of *P. paradoxa*.⁷² With regard to the antioxidant assays, the 95% ethanol extract showed DPPH and ABTS radical scavenging ability as well as ferric reducing antioxidative capacity in a dose-dependent manner. In the CUPRAC assay, copper ions were reduced by 95% ethanol extract in a dose-dependent manner.⁷²

4.59. *Prasiola japonica*. According to Park et al., loliolide, a monoterpenoid hydroxylactone from *P. japonica*, was found to remarkably reduce the melanin content and secretion in α -MSH-stimulated B16F10 cells. In the ABTS antioxidant assay, the IC_{50} value of loliolide was $61.52 \pm 2.12 \mu\text{M}$.⁷³

4.60. *Pterocarpus marsupium*. Deguchi et al. studied the antimelanogenesis, antityrosinase, and antioxidant properties of *Pterocarpus marsupium* heartwood extract by using B16 cells, mushroom tyrosinase activity assay, and DPPH assay.⁷⁴ In the melanin content assay, the concentrations of 5 , 10 , 20 , and $50 \mu\text{g/mL}$ of extracts presented 24% , 45% , 53% , and 69% inhibition of melanogenesis in B16 cells, respectively, while in the mushroom tyrosinase activity assay, the concentrations of 12.5 , 50 , and $200 \mu\text{g/mL}$ of extracts exerted 23% , 53% , and 71% mushroom tyrosinase activity, respectively. The concentration of 10 , 20 , and $50 \mu\text{g/mL}$ of extracts demonstrated 16% , 33% , and 73% DPPH radical-scavenging activity, which were comparable to 10 , 20 , and $50 \mu\text{g/mL}$ of ascorbic acid of 15% , 31% , and 84% DPPH radical-scavenging activity.⁷⁴

4.61. Red maple (*Acer rubrum*). Ma et al. reported that the antimelanogenesis activity of Ginnalin A from red maple leaves at 25 and $50 \mu\text{M}$ effectively reduced the melanin content in B16F10 cells to 79.1% and 56.7% , respectively.⁷⁵ Ginnalin A also exhibited the strongest tyrosinase inhibitory effect in the mushroom tyrosinase activity assay, with an IC_{50} of $101.4 \pm 6.5 \mu\text{M}$, followed by Maplexin J ($173.8 \mu\text{M}$) and Maplexin F ($208.9 \pm 3.1 \mu\text{M}$). However, Ginnalin B and Ginnalin C showed poor tyrosinase inhibition with $IC_{50} > 500 \mu\text{M}$ reported. For reference, the tyrosinase inhibition IC_{50} of kojic acid was $23.7 \pm 0.9 \mu\text{M}$, while arbutin was $61.6 \pm 2.8 \mu\text{M}$. Lastly, $50 \mu\text{M}$ of Ginnalin A was reported to reduce ROS levels to 55.1% in B16F10 cells.⁷⁵

4.62. *Rosa chinensis* cv. "JinBian". Li et al. investigated the antioxidant activity of *Rosa chinensis* cv. "JinBian" with different types of solvent extraction including 95% ethanol, 65% ethanol, and petroleum ether. The results presented that

95% ethanol has the highest DPPH free radical scavenging ability of $94.36 \pm 0.12\%$, followed by 65% ethanol ($94.11 \pm 0\%$), both comparable to the standard Trolox with $95.12 \pm 0.29\%$ DPPH activity. Besides, 95% ethanol also exhibited the highest tyrosinase inhibitory activity of $66.95 \pm 0.27\%$, while α -arbutin was only reported to be $22.15 \pm 0.42\%$. Nonetheless, petroleum ether showed limited antioxidant and antityrosinase activities, with $17.25 \pm 1.45\%$ DPPH activity and $6.27 \pm 0.68\%$ tyrosinase inhibition reported.⁷⁶

4.63. *Rubus caesius* L. Grochowski et al. examined the antityrosinase and antioxidant activities of *Rubus caesius* L. leaf extract with various solvent extraction methods and partitioned.⁷⁷ The tyrosinase inhibitory effect of all extracts was arranged in the order of *n*-BuOH (RC6) > pure MeOH (RC3) > 50% MeOH (RC2) > water (RC1) > EtOAc (RC5) > diethyl ether (RC4), with the values of 63.12 ± 0.26 , 61.83 ± 0.26 , 61.82 ± 1.43 , 60.59 ± 0.37 , 56.92 ± 0.70 , and 55.32 ± 0.67 mg KAE/g extract, respectively. In view of the DPPH and ABTS radical scavenging properties, RC4, RC5, and RC6 exhibited similar scavenging activity which was more powerful than the other extracts, with the values of 1.58 ± 0.01 , 1.58 ± 0.01 , and 1.55 ± 0.02 mmol TE/g extract (DPPH) and 2.45 ± 0.03 , 2.92 ± 0.03 , and 2.02 ± 0.03 mmol TE/g extract (ABTS), respectively. The RC5 showed the highest CUPRAC at 4.98 ± 0.05 mmol TE/g extract, followed by RC4 (3.49 ± 0.02 mmol TE/g), RC6 (2.82 ± 0.18 mmol TE/g), RC2 (1.63 ± 0.02 mmol TE/g), RC3 (1.60 ± 0.05 mmol TE/g), and RC1 (0.34 ± 0.01 mmol TE/g). The same trend was reported in the FRAP assay, as RC5 (2.78 ± 0.1305 mmol TE/g) > RC4 (2.15 ± 0.08 mmol TE/g) > RC6 (1.71 ± 0.21 mmol TE/g) > RC2 (1.05 ± 0.03 mmol TE/g) > RC3 (0.92 ± 0.04 mmol TE/g) > RC1 (0.22 ± 0.01 mmol TE/g). In the phosphomolybdenum (PM) assay, RC5 (3.92 ± 0.34 mmol TE/g) was the highest, followed by RC6 (3.10 ± 0.26 mmol TE/g) and RC4 (2.58 ± 0.11 mmol TE/g), while RC1 showed the least effect at 0.59 ± 0.02 mmol TE/g. Notably, RC2 showed the strongest metal chelating effects with 16.62 ± 1.71 mg EDTAE/g, followed by RC3 (14.67 ± 1.13 mg EDTAE/g) and RC6 (12.94 ± 0.87 mg EDTAE/g).⁷⁷

4.64. *Scabiosa columbaria*. Otang-Mbeng and Sagbo explored the antimelanogenesis property of *Scabiosa columbaria* leaf extract in melanin content assay using B16F10 melanoma cells.⁷⁸ Results showed that the extracts inhibited melanogenesis in α -MSH-stimulated B16F10 cells with increasing concentrations, and the cellular melanin content was decreased to around 40% at 100 μ g/mL of extract concentration. The antityrosinase activity of the extracts was also reported in a dose-dependent manner. In the antioxidant assay, the extracts displayed a more significant FRAP activity than Trolox, especially at 200 μ g/mL.⁷⁸

4.65. *Schinus terebinthifolius*. Sassi et al. reported that *Schinus terebinthifolius* leaf extracts by using methanol showed $100 \pm 0.0\%$ of tyrosinase inhibitory effect, while acetone and hexane extracts showed 92.10 ± 1.81 and $73.68 \pm 1.56\%$ inhibition, respectively. All of the leaf extract was found to be comparable to the positive control, kojic acid, with $86.7 \pm 1.75\%$ inhibition reported. Interestingly, acetone fruit extract showed the highest tyrosinase inhibition ($78.94 \pm 1.2\%$) among other fruit extracts, as methanol fruit extract was found with $63.15 \pm 1.43\%$ and oil extracts with only $5.26 \pm 0.6\%$ tyrosinase inhibition. The DPPH and ABTS assays revealed that oil extract of *Schinus terebinthifolius* fruit has the highest radical scavenging activity, with an IC_{50} value of 0.016 and 0.017 mg/mL, respectively, stronger than the Trolox

(DPPH = 0.136 mg/mL; ABTS = 0.145 mg/mL). Other than that, both leaf and fruit methanol extract also exhibited promising radical scavenging activity, with IC_{50} values of 0.53 and 0.41 mg/mL in the DPPH assay, as well as 0.76 and 0.61 mg/mL in the ABTS assay.⁷⁹

4.66. *Schisandra chinensis* (Turcz.) Baillon. According to Lee et al., the melanin inhibitory values (IC_{50}) of *Schisandra chinensis* (Turcz.) Baillon dried fruit extracts with *n*-hexane were the strongest (11.58 μ g/mL), followed by CH_2Cl_2 (27.89 μ g/mL) and 95% ethanol (98.37 μ g/mL), while IC_{50} values for EtOAc, *n*-BuOH, and water extracts were all higher than 100 μ g/mL.²

4.67. *Scorzonera tomentosa* L. Dall'Acqua et al. examined the tyrosinase inhibitory potential and antioxidant properties of the extracts of *Scorzonera tomentosa* L. aerial parts and roots by using different solvents.⁸⁰ Remarkable tyrosinase activities were reported in all extracts of both plant parts, with methanolic extracts (aerial parts = 64.83 ± 0.28 ; roots = 65.46 ± 0.31 mg KAE/g) being the most potent, while water extracts (aerial parts = 16.40 ± 1.30 ; roots = 6.29 ± 0.50 mg KAE/g) were the least effective. Dichloromethane, ethyl acetate, and hexane extracts showed moderate tyrosinase inhibition activities with values from 57.54 ± 0.12 to 63.32 ± 0.22 mg of KAE/g (aerial parts) and values from 59.99 ± 0.19 to 63.54 ± 0.56 mg of KAE/g (roots), respectively. From the DPPH and ABTS assays, methanolic and aqueous extracts of both plant parts showed good free radical scavenging ability, while no activity was displayed by the hexane aerial part extract in the DPPH assay. For the CUPRAC assay, methanolic extracts of both plant parts showed the highest activity (aerial parts: 164.06 ± 1.26 and roots: 93.18 ± 1.58 mgTE/g), while for the FRAP assay, methanolic extracts of roots (79.78 ± 0.27 mgTE/g) and aqueous extracts (41.36 ± 0.10 mgTE/g) of aerial parts were excellent sources of reducing agents. The metal chelating activity for the tested extracts of aerial parts ranged from 2.13 ± 0.10 mg (aqueous) to 13.92 ± 0.86 mg (dichloromethane) EDTAE/g, while extracts of roots reported a metal chelating activity ranging from 0.53 ± 0.07 mg (methanol) to 6.24 ± 0.17 mg (dichloromethane) EDTAE/g. Aqueous and hexane root extracts showed no metal chelating activity.⁸⁰ Lastly, moderate activity was reported for all plant part extracts in the PM assay.⁸⁰

4.68. *Sorghum bicolor*. Han et al. evaluated the antimelanogenesis activity of various concentrations of ethanol extracts of *Sorghum bicolor*, and 60% ethanol extract significantly decreased the melanin contents from 316.85% to 108.60%, which was comparable to that for kojic acid (101.79%).⁸¹ The 60% ethanol extract has been found to have the highest total phenolic content compared with other concentrations of ethanol extracts. The above two findings revealed that the total phenolic and flavonoid contents were positively correlated with free radical scavenging ability and tyrosinase inhibition, which contributed to their strong antimelanogenesis properties. Besides, the tyrosinase inhibition IC_{50} of 60% ethanol extract was 89.25 μ g/mL (L-tyrosine), comparable to the arbutin of 74.35 μ g/mL; however, no results were reported for L-DOPA.⁸¹ With regard to the DPPH and ABTS assays, the IC_{50} values of 60% ethanol extract were 612.53 and 409.71 μ g/mL, respectively. In the MDA assay, the 60% ethanol extract was reported with an IC_{50} value of 16.56 μ g/mL.⁸¹

4.69. *Stenocarpus sinuatus*. According to Younis et al., the tyrosinase inhibitory effect (IC_{50}) of hexane soluble

fraction from *Stenocarpus sinuatus* leaf extract was 67.5 $\mu\text{g/mL}$, while 13.8 $\mu\text{g/mL}$ was reported in kojic acid.⁸²

4.70. *Tricholysurus goniospermum*. Angelini et al. examined the antityrosinase and antioxidant activities of *n*-hexane, ethyl acetate, and methanol extracts from fruiting bodies and liquid-cultured mycelia of *T. goniospermum*.⁸³ From the results obtained, the ethyl acetate extracts displayed the most effective tyrosinase inhibition with fruiting body extracts of 554.30 ± 9.41 mg KAE/g and mycelia extracts of 412.81 ± 1.39 mg KAE/g. Besides, *n*-hexane extracts showed a better tyrosinase inhibition than methanol, with 83.80 ± 1.45 and 48.48 ± 0.07 mg KAE/g (fruiting bodies extracts) and 127.76 ± 0.73 and 28.17 ± 0.39 mg KAE/g (mycelia extracts), respectively. The results from the colorimetric enzyme inhibition assay were consistent with the antioxidant assays, as ethyl acetate extracts exhibited the strongest antioxidant capacity [DPPH = 88.82 ± 1.47 (fruiting bodies) and 29.93 ± 3.54 (mycelia) mg TE/g; CUPRAC = 307.71 ± 3.83 (fruiting bodies) and 155.31 ± 1.85 (mycelia) mg TE/g; FRAP = 134.06 ± 1.50 (fruiting bodies) and 74.26 ± 1.79 (mycelia) mg TE/g], followed by methanol and *n*-hexane extracts. In general, fruiting body extracts displayed better antioxidant activity than mycelia extract, while methanol extracts showed stronger antioxidant capacity than *n*-hexane extracts, except for the mycelia extracts in FRAP assay (methanol = 12.94 ± 1.33 ; *n*-hexane = 15.15 ± 1.62 mg TE/g).⁸³

4.71. *Vigna subterranea* (Bambara Groundnut (BG)). Chutoprapat et al. reported that hull extracts of *Vigna subterranea* obtained by maceration extraction presented the highest antimelanogenesis activity with an inhibition rate of $72.90 \pm 0.08\%$, compared to hull extracts obtained by Soxhlet extraction and boiling and seed extracts obtained by maceration extraction, Soxhlet extraction, and boiling.⁸⁴ It was also superior to kojic acid, with an inhibition rate of only $45.35 \pm 0.28\%$. Further, it also has good antityrosinase and antioxidant activities that contribute to its high antimelanogenesis activity. To be specific, the hull extracts prepared by Soxhlet exhibited the most effective tyrosinase inhibition (0.07 ± 0.07 mg/mL), followed by hull extracts prepared by maceration (0.45 ± 0.23 mg/mL), comparable to the positive control, kojic acid, of 0.05 ± 0.03 mg/mL. Hull extracts prepared by maceration also displayed the strongest DPPH scavenging activity and the highest capacity in the modified Ferric-thiocyanate method, with SC_{50} of 0.87 ± 0.02 mg/mL and LC_{50} of 0.70 ± 0.06 mg/mL, respectively. Also, the seed extracts prepared by boiling exhibited the strongest metal chelating activity as an MC_{50} of 0.63 ± 0.04 mg/mL, lower than the EDTA standard of 0.73 ± 0.08 mg/mL. This study revealed that the antimelanogenesis activity was shown to be influenced by the plant parts and extraction method as the authors stated that different extraction methods may exhibit different biological activities by successful isolation of valuable phytochemical constituents.⁸⁴

4.72. *Vitis vinifera* L. (White Grape Pomace). Ferri et al. reported that ethanol extracts of both white grape wet and dried pomace had stronger antityrosinase activity (inhibition rate of 63% to 79%) than aqueous extracts (inhibition rate of 43% to 71%). To be specific, the dried pomace samples showed better tyrosinase inhibition than wet pomace.⁸⁵ On the other hand, aqueous and ethanol extracts of wet pomace were reported to have a higher antioxidant activity than dried pomace samples. Nevertheless, ethanol extracts of both wet and dried pomace showed antioxidant activity stronger than

that of aqueous extracts. In terms of anti-inflammatory activity, the results showed that aqueous extract of dried pomace exhibited better effects than dried pomace extract, while there was no activity reported for ethanol extracts.⁸⁵

4.73. *Ziziphora taurica*. Sarikurkeu et al. and coresearchers reported that the methanol extract of *Ziziphora taurica* possessed the strongest tyrosinase inhibition activity with the lowest IC_{50} of 1.25 ± 0.01 mg/mL, followed by ethyl acetate with an IC_{50} of 1.40 ± 0.06 mg/mL.⁸⁶ Methanol extract also possessed the strongest DPPH scavenging potential ($\text{IC}_{50} = 4.75 \pm 0.12$ mg/mL) and the lowest $\text{IC}_{50} = 1.14 \pm 0.06$ mg/mL in the FRAP assay. Notably, the aqueous extract showed the strongest ABTS scavenging and ferrous chelating activities with IC_{50} values of 2.61 ± 0.26 and 1.04 ± 0.01 mg/mL, respectively. Ethyl acetate was reported to have the lowest IC_{50} value of 1.80 ± 0.03 mg/mL in the CUPRAC assay. The authors further explained that the amount of phenolic content was strongly determined by the polarity of the solvent used. Methanol is a highly polar solvent and very effective in extracting phenolic compounds.⁸⁶

4.74. *Ziziphys jujuba*. Molagoda et al. reported the antimelanogenesis of seed extracts of *Ziziphys jujuba* by using quantification of extracellular and intracellular melanin content assays using B16F10 melanoma cells.⁷ The extracellular melanin content was inhibited from $147.7 \pm 5.2\%$ to $106.8 \pm 1.9\%$ by 6'-feruloylspinosin (FRS), $117.4 \pm 0.5\%$ by jujuboside B (JUB), and $119.9 \pm 2.0\%$ by epiceanthoic acid (EPA). Similarly, intracellular melanin content was inhibited from $153.5 \pm 3.3\%$ to $101.4 \pm 2.9\%$ by FRS, $113.8 \pm 2.1\%$ EPA, and $114.7 \pm 1.5\%$ JUB. The phenylthiourea (PTU) extracellular melanin inhibition result was $92.4 \pm 2.4\%$, and it was $95.3 \pm 30.2\%$ intracellularly. The highest tyrosinase inhibition was found in FRS ($45.7 \pm 2.7\%$), followed by EPA ($38.4 \pm 3.1\%$), JUB ($33.9 \pm 4.5\%$), betulin (BTL) ($11.2 \pm 5.1\%$), and lastly jujuboside A (JUA) ($7.4 \pm 5.3\%$), while the reference value from PTU was $58.4 \pm 1.0\%$.⁷

4.75. *Zizyphus lotus*. Marmouzi et al. found that *Zizyphus lotus* fruit extracts have superior antioxidant activity with a lower IC_{50} value compared to leaf extracts.⁸⁷ With regard to the DPPH and ABTS assays, the fruits extract showed stronger radical scavenging activities with IC_{50} values of 74.87 ± 16.74 and 46.31 ± 11.02 mg TE/g, respectively, compared to the leaf of 241.75 ± 17.37 and 301.34 ± 8.26 mg TE/g, respectively.⁸⁷ On the other hand, the FRAP results of fruit extract were 55.30 ± 2.30 mg AAE/g, while that for leaf extract was 160.10 ± 2.30 mg AAE/g.⁸⁷ Nevertheless, the *Zizyphus lotus* extracts possessed remarkable tyrosinase inhibition, as the IC_{50} value of fruit extract was 70.23 ± 5.94 $\mu\text{g/mL}$, while the leaf extract was 129.11 ± 9.40 $\mu\text{g/mL}$, compared to the quercetin 246.90 ± 1.90 $\mu\text{g/mL}$ reference value.⁸⁷ These two findings revealed that the extracts with good antioxidant activity possessed significant antityrosinase activity.⁸⁷

5. CONCLUSION AND OUR PERSPECTIVES

This review summarized information on the depigmentation effects of various natural plant species. Plants are rich in polyphenols including phenolic and flavonoid compounds that may have the potential to develop as a skin-whitening agent in the cosmeceutical and pharmaceutical industry.⁹² From Table 1, we concluded that the use of natural plants as skin-whitening agents is highly effective as there is a significant correlation between the content of polyphenol compounds and antimelanogenesis, antityrosinase, and antioxidant activities.

However, it is worth noting that the use of extraction methods or types of solvents is very important in determining the biological activities of plants. Further research is required to explore the most suitable extraction methods and types of solvent to obtain extracts or bioactive compounds that exhibit the most promising biological activities. Thus, use of nonconventional extraction methods can be employed as they are faster and provide high extraction yields. Additionally, we can investigate the bioactive compounds in the plant extracts regarding their structure and function that may be responsible for different biological properties. By evaluating the structures, this can aid in understanding the structure–activity relationship between the bioactive compounds and depigmentation effects as well as the mechanism of inhibition effects. For instance, nuclear magnetic resonance (NMR) spectroscopy is very useful in understanding the structure and identity of bioactive compounds. Given the adverse effects of using skin-lightening products that are made of chemicals that are hazardous to humans and the environment, more research should be done to develop safe, environmentally friendly, and effective skin-whitening agents.

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Notes

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