Current **A**pplied **S**cience and **T**echnology e-ISSN: 2586-9396

Curr. Appl. Sci. Technol. ….., Vol... (No...), e0269318

Review article

Phytochemical Study of Orchidaceae: Composition, Bioactivity and Potential Application in Functional Foods

Syntiya Inanda Khoidir[1]*, Deksa Aldebaran[1], Nur Aniza Aprilia[1] and Dimas Setyadi Putra[2,3]

[1]Department of Food Science and Biotechnology, Faculty of Agricultural Technology, Universitas Brawijaya, Malang, East Java, Indonesia
[2]Department of Pharmacology and Clinical Pharmacy, Faculty of Pharmacy, Universitas Padjadjaran, Sumedang, West Java, Indonesia
[3]Center of Excellence for Pharmaceutical Care Innovation, Faculty of Pharmacy, Universitas Padjadjaran, Sumedang, West Java, Indonesia

Received: 27 September 2025, Revised: 5 January 2026, Accepted: 10 February 2026, Published: 20 July 2026

Abstract

The family Orchidaceae is one of the most taxonomically diverse groups of angiosperms, recognized for their ornamental significance and their content of pharmacologically relevant secondary metabolites. This review critically evaluates the phytochemical diversity, bioactivities, and potential of Orchidaceae species as natural sources for the development of functional food products. This review is based on a comprehensive literature survey of 32 peer-reviewed articles indexed in Scopus and PubMed through April 2025, which reports the presence of diverse bioactive compounds-mainly phenolics, flavonoids, alkaloids, tannins, and anthocyanins in various orchid species and plant tissues. These compounds exhibit a broad spectrum of biological activities, including antioxidants, antimicrobial, anticancer, anti-inflammatory, antidiabetic, anti-aging, photoprotective, and neuropharmacological effects. The concentration and composition of these metabolites depend on species differences, plant organ specificity, and extraction methods. Cumulative evidence underscores the underutilized potential of orchids as phytochemical reservoirs for nutraceutical applications. However, further translational research on bioavailability, safety, and functional stability in complex food systems is essential to enable their practical application in consumer health products. This review advocates intensive multidisciplinary research on Orchidaceae to open up new opportunities in the functional food and health-promoting bioactive industries.

Keywords: phytochemical; orchid; secondary metabolite; functional food

*Corresponding author: E-mail: syntiyainandakhoidir@gmail.com
https://doi.org/10.55003/cast.2026.269318

1. Introduction

The Orchidaceae family represents one of the most extensive collections of flowering plants, comprising over 29,000 species and found across a range of tropical and subtropical environments (Perkins et al*.,* 2023). These flowering plants account for roughly one-tenth of all flowering plants, and include epiphytes, saprophytes, and terrestrials (Zhang et al*.,* 2017). Orchids, which are found all over the world save in deserts and at the poles, are regarded as one of the most intriguing and diverse plant groupings among angiosperms. In addition to being decorative plants, certain species of orchids contain phytochemicals that are helpful to human health and have been utilized in traditional medicine. Several orchid species, including *Coelogyne*, *Cymbidium*, *Dendrobium*, *Vanda*, and related genera, have had their chemicals extracted and used as cosmetic, therapeutic, and scent elements (Gantait et al*.,* 2021; Bazzicalupo et al*.,* 2023).

Orchids have been used traditionally to cure a variety of ailments, including coughs, stomach aches, heart attacks, malaria, tuberculosis, asthma, bronchitis, ringworm, rheumatism, and kidney issues (Parveen et al*.,* 2018). Asia is considered to be the center of orchid medicinal plants because 70% are found here (Wati et al*.,* 2023). Several orchids have been used as food ingredients and traditional medicine due to the presence of various phytochemicals with high biological activity (Nguyen et al., 2018). Secondary metabolite chemicals found in orchids, including flavonoids, alkaloids, stilbenoids, phenolics, and their derivates have been proven to exhibit biological effects such as antioxidants, antimicrobials, and anti-inflammatories (Khan et al*.,* 2019; Rahman et al*.,* 2022; Suphrom et al*.,* 2024). These chemicals are created in response to a variety of environmental challenges, and while not required for primary plant growth, they play an important role in adaptation and biological defense. Orchids are a good choice for the creation of functional foods due to the abundance and diversity of the natural chemicals they produce.

A specified grasp of the potential of orchid plants is required for the development of functional foods. Functional foods are those that, in addition to their nutritional value, provide measurable physiological benefits. Beyond their ornamental value, several medicinal orchids have been traditionally used as food ingredients and health-related products. Nguyen et al*.,* (2018) reported orchids as anti-inflammatory, anti-cholinesterase, antibacterial, supporting their classification as both traditional medicines and potential functional food ingredients. However, the Orchidaceae family is largely understudied and infrequently mentioned in the literature. Orchids may improve the immune system and lower the risk of cardiovascular disease, diabetes, digestive function, and cancer (Nguyen et al*.,* 2018; Parveen et al*.,* 2018; De, 2022). Further research into this flora will increase our understanding of its phytochemical composition and bioactive properties. This information has the potential to help expand applications in the functional food industry while also improving food security. The purpose of this article is to determine the types and compositions of phytochemical substances found in various orchid species, assess their biological activities, and investigate their potential for use as functional foods.

2. Research Methodology

Papers on orchid plants with phytocompounds and bioactivity properties published up until 26th April 2025 are included in this review. Two databases, PubMed/MEDLINE and Scopus, were used to obtain the published papers. Search terms included combinations of ("orchid" or "orchid plant" or "orchid flower") and ("secondary metabolite" or "Metabolic byproduct" or "phytochemical compound" or "secondary compound" or "secondary plant metabolite"

or "bioactive" or "phytochemistry"). A total of 289 articles covering until 4th May 2025 were obtained; after eliminating duplicates and irrelevant, 32 articles were used for this review. This paper excludes studies other than original research, studies of orchid fungi, and anything not related to the study of bioactive compounds and bioactivity from orchid plants. Plants in the Orchidaceae family that contain bioactive compounds were the focus of the basic search.

3. Secondary Metabolite from Orchid Plants

Orchid plants contain phytochemical compounds such as flavonoids, alkaloids, sterols, anthocyanins, and carotenoids. Several secondary metabolites have been isolated from *Dendrobium* orchids including moscatin, moscatilin, defuscin, cumulatin, gigantol, dendrophenol, rotundatin, and crepaditin (Bhattacharyya et al., 2015). The content of secondary metabolite compounds in orchids can vary depending on the type, part of the plant, and the solvent used. Table 1 shows the phytochemical components of various types and parts of orchid flowers.

3.1 Phenolics

Phenolic compounds are one of the most abundant secondary metabolites in orchid species. The highest content of phenolics was found in *Vanda cristata* leaves, reaching 674.49 mg GAE/g DW (Pathak et al*.,* 2023), followed by *Phalaenopsis* 'Sogo Meili' flowers at 446.22 mg GAE/g DW (Nguyen et al*.,* 2018). Meanwhile, species such as *Dendrobium thyrsiflorum* also showed high phenolic levels, especially in the stems (75.66 mg GAE/g DW) (Bhattacharyya et al*.,* 2015). These differences in phenolic content reflect the influence of plant parts, species, and solvent used. In general, these results are in line with previous studies showing that phenolics in orchids act as strong antioxidants and have antimicrobial, anti-inflammatory, and anticancer activities (Hossen et al*.,* 2024). Phenolics such as sinapic acid and ferulic acid have also been identified in *Dendrobium* Sonia 'Earsakul' flowers by ultra performance liquid chromatography (UPLC) (Kanlayavattanakul et al*.,* 2018), indicating the diversity of phenolic structures possessed by orchids.

3.2 Flavonoids

Flavonoids were found in substantial amounts in various species, with the highest value resulting from *Vanda cristata* leaves at 1030.80 mg RE/g DW (Pathak et al*.,* 2023), indicating its great potential as a source of antioxidants. *Phalaenopsis* 'Queen Beer' presented a high content, specifically 138.70 mg QE/g DW (Nguyen et al*.,* 2018). On the other hand, some species such as *Dendrobium* Shavin white had lower flavonoid levels, namely 1.24 mg QE/g (Athipornchai & Jullapo, 2018). These differences in flavonoid content can be attributed to genetic variation, geographical location, and ecological adaptation. Flavonoids such as kaempferol-3-O-rutinoside and epicatechin were identified in *Himantoglossum robertianum*, confirming the complexity of flavonoid structures in orchid species (Bazzicalupo et al*.,* 2019). These compounds are known to have a biological role as a protector against oxidative stress, as well as increasing the therapeutic value of plant extracts (Roy et al*.,* 2022).

Table 1. Secondary metabolites from different types and parts of orchids

Species	Part of Plant	Secondary Metabolite Content	Reference
Dendrobium Sonia 'Earsakul'	Flower (ethanol extract)	Phenolics (92.2 mg/g GAE extract), anthocyanin (1.952 mg/g), tannin (0.043 mg/g extract), pelargonidin (0.365 mg/g extract), cyanidin (0.015 mg/g), sinapic acid (0.126 mg/g extract), ferulic acid (0.121 mg/g extract)	(Kanlayavattanakul et al*.,* 2018)
Dendrobium Pearl Vera	Whole plants (ethanol extract)	Total phenolic (13.3 mg GAE/ g extract), flavonoid (28.5 mg QE/g extract), quercetin (0.64 mg/g extract)	(Swainson et al*.,* 2023)
Malaxis acuminata D. Don	Leaf and stem (methanol extract)	Leaf: phenolic (37.89 mg GAE/g DW), flavonoids (20.13 mg QE/g DW), alkaloids (33.76 mg AE/g DW), tannins (33.44 mg TAE/g DW). Stem: phenolic (44.34 mg GAE/g DW), flavonoids (24.56 mg QE/g DW), alkaloids (45.12 mg AE/g DW), tannins (19.58 mg TAE/g DW), also contain oleic acid, stearic acid, galactose, fructose, levoglucosan, fumaric acid, succinic acid, p-coumaric acid, L-alanine, glycine, serine, stigmasterol, and b-sitosterol	(Bose et al*.,* 2017)
Dendrobium Sonia	Flower (ethanol extract)	Total phenolic (5.19 mg GAE/g) and total flavonoids (3.80 mg QE/g)	(Athipornchai & Jullapo, 2018)
Dendrobium Sonia pink	Flower (ethanol extract)	Total phenolic (4.86 mg GAE/g) and total flavonoids (4.01 mg QE/g)	(Athipornchai & Jullapo, 2018)
Dendrobium Shavin white	Flower (ethanol extract)	Total phenolic (5.34 mg GAE/g) and total flavonoids (1.24 mg QE/g)	(Athipornchai & Jullapo, 2018)

Table 1. Secondary metabolites from different types and parts of orchids (continued)

Species	Part of Plant	Secondary Metabolite Content	Reference
Himantoglossum robertianum	Flower (ethanol extract)	Total phenol content (2.44 mg GAE/g fresh weight), flavonoids (3.98 mg QE/g FW), anthocyanins (0.049 mg ChE/g FW), flavan-3-ols (0.033 mg CatE/g FW), proanthocyanidins (0.0005 mg CyE/g FW), caempferol-3-O-rutinoside (0.021 mg/g FW), catechin (0.026 mg/g FW), epicatechin (0.099 mg/g FW), caffeic acid (0.012 mg/g FW)	(Bazzicalupo et al., 2019)
Dendrobium thyrsiflorum	Stem, leaf, and root (methanol extract)	Stem: total phenolic compounds (75.66 mg GAE/g DW), flavonoids (8.23 mg QE/g DW), alkaloids (35.44 mg ATP/g DW). Leaves: total phenolic compounds (48.67 mg GAE/g DW), flavonoids (15.52 mg QE/g DW), alkaloids (69.32 mg ATP/g DW). Root: total phenolic compounds (27.67 mg GAE/g DW), flavonoids (3.55 mg QE/g DW), alkaloids (22.33 mg ATP/g DW)	(Bhattacharyya et al., 2015)
Dactylorhiza romana subsp. *georgica*	Tuber (ethyl acetate extract)	Phenolic (29.15 mg GAE/g extract), flavonoid (6.97 mg QE/g extract), chlorogenic acid (0.051 mg/g extract), syringic acid (0.029 mg/g extract), vanillin (0.018 mg/g extract), benzoic acid (0.015 mg/g extract), cinnamic acid (0.064 mg/g extract), luteolin (0.0175 mg/g extract)	(Kotiloğlu et al., 2020)
Dendrobium crepidatum	Stem (ethanol extract)	Phenolic (0.078 mg GAE/g extract) and flavonoid (61.57 mg QE/g extract)	(Paudel et al., 2019)

Table 1. Secondary metabolites from different types and parts of orchids (continued)

Species	Part of Plant	Secondary Metabolite Content	Reference
Prosthechea karwinskii	Pseudobulbs, leaves, and flowers (ethanol extract)	Leaves: total phenols (142.95 mg GAE/g) and flavonoids (11.24 mg QE/g) Flower: total phenols (22.06 mg GAE/g) and flavonoids (0.22 mg QE/g)	(Barragán-Zarate et al., 2022)
Anacamptis pyramidalis (L.) Rich.	Tuber (methanol extract)	Total phenolic content (17.03 mg GAE/g extract), flavonoid (0.48 mg RE/g extract) Other chemical compounds: gastrodin, and caffeic acid derivatives	(Mahomoodally et al., 2020)
Acampe papillosa	Stem (ethanol extract)	Phenol (49 mg GAE/g), flavonoid (0.171 mgQE/g), tannin (3.17 mg TAE/g), alkaloid (107 mg/g), saponin (72 mg/g)	(Natta et al., 2022)
Dendrobium densiflorum	Leaf (ethanol extract)	Total phenol (30.4 mg GAE/g), flavonoid (0.355 mg QE/g), tannin (19,3 mgTAE/g), alkaloid (117 mg/g), saponin (22 mg/g)	(Natta et al., 2022)
Eulophia nuda Lindl.	Fresh corms (methanol extract)	Phenolic acid derivative quantification by maceration- HPLC: gallic acid (0.026 mg/mL), protocatechuic acid (0.070 mg/mL), caffeic acid (0.016 mg/mL), syringic acid (0.054 mg/mL), vanillic acid (16.65 µg/mL), ferulic acid (0.009 mg/mL), and quercetin (0.005 mg/mL)	(Misra et al., 2023)
Phalaenopsis 'Queen Beer' (purple)	Flower (methanol extract)	Polyphenols (179.61 mg GAE/g DW), flavonoids (138.70 mg QE/g DW), chlorophyll a (0.05 mg/g DW), chlorophyll b (0.11 mg/g DW), carotenoids (0.22 mg/g DW)	(Nguyen et al., 2018)

Table 1. Secondary metabolites from different types and parts of orchids (continued)

Species	Part of Plant	Secondary Metabolite Content	Reference
Phalaenopsis 'Sogo Meili' (yellow)	Flower (methanol extract)	Polyphenols (446.22 mg GAE/g DW), chlorophyll a (0.25 mg/g DW), flavonoids (21.62 mg QE/g DW), anthocyanin (14.45 μmol/g DW), chlorophyll b (0.12 mg/g DW), carotenoids (0.82 mg/g DW)	(Nguyen et al*.,* 2018)
Vanda cristata Wall.	Leaf (methanol extract)	Flavonoids (1030.80 mg RE/g DW) and phenols (674.49 mg GAE/g DW); Phytol, d-Tocopherol (Vitamin E), n-Hexadecanoic acid, Eugenol, Stigmasterol, g-Sitosterol, Campesterol, Methyl stearate, 9,12-Octadecadienoic acid, and methyl ester	(Pathak et al*.,* 2023)
Dendrobium moniliforme	Stem (ethanol extract)	Total phenol content (98.42 mg GAE/g), flavonoid (110.31 mg QE/g),5-(Hydroxymethyl)-2 furancarboxaldehyde, 2,3-Dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, 2-Methoxy-4-vinylphenol, Phenol, 2,6-dimethoxy, γ-Sitosterol, Stigmast-5-en-3-ol	(Paudel et al*.,* 2018)
Dendrobium 'Sonia Jo Daeng'	Flower (methanol extract)	Phenolic compounds (7.23 mg GAE/g DW), and polysaccharides (153.95 mg glucose/g polysaccharide)	(Obsuwan et al*.,* 2019)

3.3 Alkaloids

Alkaloids are found widely distributed in orchid tissues, with high levels in Malaxis acuminata stems (45.12 mg AE/g DW) and *Dendrobium thyrsiflorum* leaves (69.32 mg ATP/g DW) (Bhattacharyya et al*.,* 2015; Bose et al*.,* 2017). In addition, the identification of 8 alkaloid compounds in *Dendrobium* Pearl Vera also indicates the diversity of chemical structures in this group (Swainson et al*.,* 2023). Alkaloids have important biological activities such as anti-inflammatory and antimicrobial (Hu et al*.,* 2016; Casciaro et al*.,* 2019). Although their pharmacological contributions have been known, the specific characterization and mechanism of action of alkaloids from orchids are still limited. Thus, further exploration of the structure and biological activities of alkaloids is urgently needed.

3.4 Tannins

Tannins are polymeric phenolic compounds that can function as astringents and antioxidant agents. The highest content was found in *Acampe papillosa* (3.17 g TAE/100 g) and *Dendrobium densiflorum* (1.93 g TAE/100 g), with extraction performed by the maceration method (Natta et al*.,* 2022). Tannins were found in *Dendrobium* Sonia 'Earsakul' flowers with content up to 42.81 µg/g in the 70% ethanol extract via the maceration-agitation method (Kanlayavattanakul et al*.,* 2018). In addition, *Malaxis acuminata* also showed significant tannin content in both its leaves and stems (Bose et al*.,* 2017). The presence of tannins contributes to the antimicrobial and antioxidant properties of orchid extracts (Natta et al*.,* 2022). However, differences in tannin compounds between studies may indicate that the extraction method and solvent used have a major influence on the quantification results.

3.5 Anthocyanins

Anthocyanins are flavonoid pigments found in high amounts in *Phalaenopsis* 'Queen Beer' (147.48 µmol/g DW) and *Dendrobium* Sonia 'Earsakul' (195.24 mg/100 g) (Kanlayavattanakul et al., 2018; Nguyen et al., 2018). Compounds such as pelargonidin and cyanidin identified through UPLC in *Dendrobium* Sonia indicated the presence of anthocyanins in the form of aglycones and glycosides. Petunidin, pelargonidin, delphinidin, cyanidin, malvidin, and peonidin are the six types of anthocyanidins (anthocyanin chromophores) that are typically found in orchids (Zhou et al*.,* 2021). Cyanidin gives orchids a red or purple hue, pelargonidin gives them a red or orange hue, peonidin gives them a red or purple hue, and delphinidin gives them a blue or purple hue. It is well known that the anthocyanin compounds found in orchids offer health benefits such as enhancing brain and heart function, and shielding body cells from the damage brought on by free radicals (Khoo et al*.,* 2017; Kumari et al*.,* 2021) This study confirms that flower color is correlated with anthocyanin content and type, which can be utilized in plant breeding and natural cosmetic formulations.

4. Orchid Plant Extracts Reported for Bioactivity

Orchidaceae is one of the largest and widest families of flowery plants having biological activity like exhibiting phytotoxic, antispasmodic, antioxidant, enzyme inhibitory, antimicrobial, and skin anti-aging effects (Kotiloğlu et al*.,* 2020). Previous phytochemical investigations of orchid plants uncovered several chemical compounds such as alkaloids, bibenzyls, flavonoids, fluorenones,

sesquiterpenes, lignans, phenanthrenes, and polysaccharides. Various types of bioactive compounds with medicinal and pharmaceutical functions, such as polyphenols, flavonoids, alkaloids, and polysaccharides, were found in these plants (Swainson et al*.,* 2023). These compounds have been shown to have anticancer, antioxidant, anti-inflammatory, neuroprotective and immunomodulatory properties (Rahamtulla et al*.,* 2023). Table 2 shows the bioactivities of different types and parts of orchids using *in vitro* and *in vivo* studies.

The phytochemical profiles reported in this review were strongly influenced by solvent polarity, as most studies employed polar solvents such as methanol and ethanol that preferentially extracted phenolics, flavonoids, and anthocyanins (Kanlayavattanakul et al., 2018; Gantait et al., 2021). As a result, non-polar or semi-polar bioactives such as sterols and terpenoid-related compounds, which have been identified in several orchid species, may be underrepresented, reflecting methodological selectivity rather than the full phytochemical diversity of Orchidaceae (Pathak et al., 2023; Hossen et al., 2024).

4.1 Antioxidant activity

The antioxidant activity of an ethanol extract from *Dendrobium* Sonia 'Earsakul' flower was investigated using the ABTS (2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulfonic) acid), DPPH (2,2-diphenyl-1-picrylhydrazyl), and FRAP (ferric reducing antioxidant power) assays. The ethanol extract showed potential scavenging activity with IC50 of 103.56 mg/mL in ABTS assay, compared to IC50 of 124.70 mg/mL in DPPH assay, and ferric reducing antioxidant power of 67.57 µg Fe^{2+}/mg (Kanlayavattanakul et al*.,* 2018). In a similar study, methanol extracts from *Phalaenopsis* 'Queen Beer' and *Phalaenopsis* 'Sogo Meili' flowers indicated potential antioxidant activity, which was determined by the DPPH, ferrous iron-chelating, and reducing power. Both extracts showed potential antioxidant activity with the highest IC50 of 16.91 and 14.79 mg/mL in DPPH assay; 1.50 and 1.02 mg/mL in ferrous iron-chelating assay; and 23.53 and 33.66 mg/mL in the reducing power (Nguyen et al*.,* 2018). An aqueous extract (400 µg/mL) of *Rhynchostylis retusa* leaf showed radical scavenging activity with the highest percentage of inhibition of 82.23% in the DPPH assay (Kumar et al*.,* 2021). It can be concluded that the parts of the orchid like flower and leaf have the highest potential for antioxidant activity.

4.2 Antimicrobial activity

Methanol tuber extracts of *Eulophia nuda* Lindl. were evaluated by Padhee et al. (2025) for antimicrobial activity using agar well diffusion method. Zone of inhibition (ZOI), minimum inhibitory concentration (MIC), and minimum bacterial concentration (MBC) were recorded. The tuber extract showed activity against *Enterococcus faecalis, Staphylococcus saprophyticus, Staphylococcus aureus, Bacillus subtilis,* and *Staphylococcus epidermidis.* Hossen et al*.,* (2024) also studied ethyl acetate extract of *Coelogyne suaveolens* from bulbs, roots, and leaves for antibacterial activities using an *in vitro* disc diffusion assay. The root extract demonstrated strong activity against *Escherichia coli* (23 mm), followed by *Staphylococcus aureus* (18 mm), *Proteus vulgaris* (17 mm), and *Klebsiella pneumoniae* (16 mm). In contrast, the bulb extracts had highest inhibition for *Salmonella typhi* (14 mm), *Pseudomonas aeruginosa* (14 mm). These findings indicate that the antimicrobial activity varies depending on both the plant part and the target microorganism. Similary, *Dactylorhiza romana* subsp. *georgica* tuber extract demonstrated antimicrobial activity against *Escherichia coli*, *Vibrio parahaemolyticus*, and *Candida albicans* (Kotiloğlu et al., 2020), indicating an antimicrobial potential of orchid-derived extracts.

Table 2. Bioactivity from different types and parts of orchids

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
		Aqueous	Antidiabetic activity	*In vitro*- α-Amylase Inhibition.	Maximum inhibition- 58.15% at 300 µg/mL concentration	
Rhynchostylis retusa	Leaf			Glucose dialysis retardation index (GDRI)	67.65% inhibition at 400 µg/mL	(Kumar et al., 2021)
			Antioxidant	DPPH	82.23% at 400 µg/mL	
Dendrobium macrostachyum Lindl.	Stems and leaves	Ethanol	Antioxidant	·DPPH	·IC50: 10.21	(Sukumaran & Yadav, 2016)
				·ABTS	·IC50: 31.54	
Dactylorhiza romana subsp. *georgica*	Tuber	Ethyl acetate	Antimicrobial	·*Escherichia coli* inhibition	·Inhibition zone: 8 mm; MIC: 8.2 mg/mL	(Kotiloğlu et al., 2020)
				·*Vibrio parahaemolyticus*	·Inhibition zone: 7 mm; MIC: 8.2 mg/mL	
				·*Candida albicans*	·Inhibition zone: 9 mm; MIC: 0.5125 mg/mL	
			Enzyme inhibitory	·A Glucosidase	·6.773 mmol ACE/g extract	
				·α-Amylase	·79.801 mmol ACE/g extract	
Dendrobium aphyllum (Roxb.),	Leaves	Methanol and ethyl acetate	Anticancer	·HepG2 (liver cancer cell)	Methanol extract showed generally stronger effects, especially against liver (HepG2) and breast cancer cells (MDA-MB 231). MDA-MB 231 (breast cancer): 77.94% cell death, IC_{50} = 45.67 µg/mL. HepG2 (liver cancer): 86.60% cell death at 250 µg/mL, IC_{50} = 46.07 µg/mL. Ethyl acetate extract had the most potent effect on colon cancer (HT29) with 75.23% cell death and the lowest IC_{50} value of 6.45 µg/mL	(Rahamtulla et al., 2023)
				·MDA-MB 231 (breast cancer cell)		
				·HT29 (colon cancer cell)		

Table 2. Bioactivity from different types and parts of orchids (continued)

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
Dendrobium Sonia 'Earsakul'	Flower	Ethanol	Antioksidan	·ABTS	· IC50 103.56 mg/mL	(Kanlayavattanakul et al., 2018)
				·DPPH	·IC50 124.70 mg/mL	
				·FRAP	·67.57 µg $FeSO_4$/mg	
			Anti Aging	·Collagenase inhibition	·81.81% inhibition	
				·Elastase inhibition	·37.29% inhibition	
				·Tyrosinase inhibition	·47.86% inhibition	
				·Cellular antioxidant (human fibroblast)	·85.68% (0.1 mg/mL)	
			Anti pigmentation	·TRP-2 (Tyrosinase-Related Protein 2) inhibition	·89.21%	
				·melanin content suppression	·17.78%	
			Anticancer	MMP-2 inhibition/ B16F10 melanoma	Pro-MMP 2 12.71% and active- MMP 2 100%	
Coelogyne suaveolens	Bulb, root, and leaf	Ethyl acetate	Antibacterial	*In vitro* (disc diffusion)	Bulb: *Staphylococcus aureus* (16 mm, zone), *Escherichia coli* (18 mm, zone), *Proteus vulgaris* (NI), *Klebsiella pneumoniae* (15 mm), *Salmonella typhi* (14 mm), *Pseudomonas aeruginosa* (14 mm)	(Hossen et al., 2024)
					Root: *Staphylococcus aureus* (18 mm), *Escherichia coli* (23 mm), *Proteus vulgaris* (17 mm), *Klebsiella pneumoniae* (16 mm), *Salmonella typhi* (NI), *Pseudomonas aeruginosa* (NI)	
					Leaf: *Staphylococcus aureus* (14 mm), *Escherichia coli* (17 mm), *Proteus vulgaris* (12 mm), *Klebsiella pneumoniae* (15 mm), *Salmonella typhi* (13 mm), *Pseudomonas aeruginosa* (15 mm)	

Table 2. Bioactivity from different types and parts of orchids (continued)

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
Rhynchostylis retusa	Roots, Stem, and Leaves	Methanol	Antimycobacterial	CRI assay (Colorimetric redox indicator assay)	MIC= 62.5 µg/mL (H37Rv), 125 µg/mL (MDR)	(Bhatnagar et al., 2017)
Tropidia curculioides	Roots, Stem, and Leaves	Methanol	Antimycobacterial	CRI assay	MIC = 125 µg/mL (H37Rv), 104.16 µg/mL (MDR)	(Bhatnagar et al., 2017)
Satyrium nepalense	Pseudobulb, Flowers, Leaves, and Stem	Methanol	Antimycobacterial	CRI assay	MIC = 15.7 µg/mL (H37Rv)	(Bhatnagar et al., 2017)
Coelogyne suaveolens	Bulb and root	Ethyl acetate	Analgesic peripheral and central	·Acetic acid-induced writhing	Peripheral:	(Eva et al., 2024)
				·Tail immersion test	bulb: 75.56% inhibition	
					root: 64.44% inhibition	
					Central:	
					bulb: 32.13% reaction time elongation	
					root: 27.22% reaction time elongation	
			Anxiolytic	Hole-board test	Bulb: 30.80 head dips	
					Root: 41.40 head dips	
			sedative	Rotarod test	Bulb: dose 400 mg/kg- time dropped to	
					Root: dose 400 mg/kg- time dropped to 126-134 s	

Table 2. Bioactivity from different types and parts of orchids (continued)

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
Malaxis acuminata D. Don	Leaf (in-vitro derived plants)	Methanol extract	Antioxidant	·DPPH	·IC50 42.66 µg/mL	(Bose et al., 2017)
				·ABTS	·IC50 13.32 µg/mL	
				·Metal chelation	·83.8%	
			Anti Aging	Enzyme inhibition:	·IC50 32.52 µg/mL	
				·Collagenase (FALGPA substrate assay)	·IC50 32.24 µg/mL	
				Elastase (SANA substrate assay)		
			Anti inflammatory	5-LOX inhibition	IC50= 60.36 µg/mL	
			Photoprotection	sun protection factor (SPF)	29.0 at 250 µg/mL	
Paphiopedilum dianthum	Root	Ethyl acetate	Anticancer	MTT assay (breast cancer cell line MCF7)	IC_{50} = 6.2 µM	(Sein et al., 2023)
			Selectivity to Cancer Cells	Selective Index (SI)	30.8 µM / 6.2 µM = ~5.0	
			Chemosensitizing Activity	Combination treatment (S5 + DOX or MX) on drug-resistant breast cancer cell lines:	OX + S5:	
				·MCF7/DOX (Doxorubicin-resistant)	·MCF7: IC_{50} reduced from 1.8 µM to 0.2 µM → CER = 8.5, CI = 0.2	
				·MCF7/MX (Mitoxantrone-resistant)	·MCF7/DOX: IC_{50} reduced from 50.2 µM to 2.5 µM → CER = 19.9, CI = 0.1	
				·MTT assay	MX+ S5:	
				Combination Index (CI)	·MCF7: CER = 3.7, CI = 0.4	
					·MCF7/MX: CER = 5.1, CI = 0.2	
					All CI < 1	

Table 2. Bioactivity from different types and parts of orchids (continued)

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
Eulophia nuda Lindl.	Tuber	Methanol	Antibacterial	·*Enterococcus faecalis*	MIC = 0.03 mg/mL	(Padhee et al., 2025)
				·*Staphylococcus saprophyticus*	·MIC = 0.06 mg/mL	
				· *S. aureus, B. subtilis*	·MIC = 0.125 mg/mL	
				·*S. epidermidis*	·MIC = 2.00 mg/mL	
			Antiproliferative	·PANC-1 (pancreas cell)	·IC50 = 29.39 mg/mL	
				· HepG2 (liver cell)	·IC50 = 38.13 mg/mL	
				·PC3 (prostat)	·IC50= 46.97mg/mL	
				·HEK-293	·IC50 = 262.47mg/mL	
Phalaenopsis 'Queen Beer' (purple)	Flower	Methanol	Antioxidant	·DPPH	·IC50: 16.91±3.54 mg/mL	(Nguyen et al., 2018)
				·Ferrous iron-chelating	·IC50: 1.50±0.23 mg/Ml	
				·Reducing power	·IC50: 23.53±1.02 mg/mL	
Phalaenopsis 'Sogo Meili' (yellow)	Flower	Methanol	Antioxidant	·DPPH	·IC50: 14.79±0.38 mg/mL	(Nguyen et al., 2018)
				·Ferrous iron-chelating	·IC50: 1.02±0.27 mg/mL	
				·Reducing power	·IC50: 33.66±5.64 mg/mL	

Table 2. Bioactivity from different types and parts of orchids (continued)

Species	Part of Plant	Type of Extract	Bioactivity	Analysis Method	Key Result	Reference
Dendrobium moniliforme	Stem	Ethanol	Antioxidant	DPPH	IC50 = 58.77 µg/mL	(Paudel et al., 2018)
			Cytotoxic activity	MTT assay	·IC50 = 772.50 µg/mL	
				·U251 cells	·IC50 = 181.93 µg/mL	
				·HeLa cells		
Cymbidium sp. (*Cymbidium* hybrids: Tethys, Jazz Festival, Tracey Reddaway, Thomas Starzl)	Pseudobulbs and roots	Ethyl acetate	Antioxidant	DPPH assay	·pseudobulb: IC50 114.18 µg/mL	
					·root: IC50 127.17 µg/mL	
			Anti aging	Enzymatic assay:	Pseudobulbs:	
				·antityrosinase	·54.19±3.72%	
				·elastase inhibition	·41.71±0.61%	
					Roots:	
					·37.50±2.54%	
					·45.99±3.25%	
Himantoglossum robertianum	Flower	Ethanol	Antioxidant	·DPPH	·IC50 211.1 ug/mL	(Bazzicalupo et al., 2019)
				·FRAP	·8.85 ug/mL	
				·Iron-chelating	·IC50 440.8 ug/mL	
			Anti aging	Cell-free assay:	·up to 42% inhibition at 500 µg/mL	
				·Elastase inhibition	·up to 78% inhibition at 500 µg/mL	
				·Collagenase inhibition		
			Cytoprotective effect	MTT assay (H_2O_2 exposure)	cell viability improved from 30% to 84% of control	

4.3 Anticancer activity

Orchid plants have been reported to exhibit remarkable anticancer properties. The anticancer properties of ethyl acetate, ethanol, or methanol extracts of a number of orchid species, including *Dendrobium aphyllum* (Roxb.), *Dendrobium* Sonia 'Earsakul', *Paphiopedilum dianthum*, and *Eulophia nuda* Lindl have been investigated. Orchid plants have anticancer capabilities because they are rich in polyphenols, flavonoids (1-6), and have strong antioxidant effects (Shukla et al*.,* 2022). On cancer cell lines, a methanol extract of *Dendrobium aphyllum* (Roxb.) leaves effectively caused cell death in liver cancer cell (HepG2), make 86.60% cell death at 250 µg/mL and IC_{50} = 46.07 µg/mL; breast cancer (MDA-MB 231) 77.94% cell death and IC_{50} = 45.67 µg/mL; and ethyl acetate extract had the most potent effect on colon cancer (HT29) with 75.23% cell death and the lowest IC_{50} value of 6.45 µg/mL (Rahamtulla et al*.,* 2023). Furthermore, selectivity index of *Paphiopedilum dianthum* root extract demonstrated promising activity (~5.0) and an IC_{50} of 6.2 µM against MCF7 cells, indicating a higher toxicity toward cancer cells (Sein et al*.,* 2023). The high IC_{50} ratio of normal cells to cancer cells indicates the presence of specific molecular targets that differ between normal and cancer cells. Additionally, the root extract significantly decreased IC_{50} and showed strong chemosensitizing properties (CI<1). These results suggest that orchids have potential properties as new sources of anticancer medications.

4.4 Enzyme inhibitory and antiaging activity

Enzyme inhibitory data indicate that orchid compounds interact with multiple enzyme targets. Simultaneous inhibition of α-amylase and α-glucosidase indicates a comprehensive glycemic control mechanism. Enzyme inhibitory activities, especially against α-amylase and α-glucosidase, showed an antidiabetic potential that has not been widely reported in Orchidaceae literature. The inhibition of α-amylase (58.15%) and glucose diffusion (67.65%) obtained from *Rhynchostylis retusa* surpassed some conventional antidiabetic plants, opening new perspectives in orchid research (Kumar et al*.,* 2021). Meanwhile, *Malaxis acuminata* extract showed inhibitory activity against collagenase and elastase, two enzymes that play a role in the degradation of collagen and elastin tissue, with IC_{50} of 32.52 and 32.24 µg/mL, respectively (Bose et al*.,* 2017). This ability was also shown by *Dendrobium* Sonia 'Earsakul' extract, which inhibited collagenase by 81.81%, elastase by 37.29%, and tyrosinase by 47.86% (Kanlayavattanakul et al*.,* 2018). This activity has potential use of orchids as anti-aging formulations, skin lightening products, and antidiabetic herbal supplements.

4.5 Other bioactivities

In addition to the main activities such as antioxidant, antimicrobial, and anticancer, several orchid species also show other bioactive potentials. One of the prominent activities is anti-inflammatory, as shown by *Malaxis acuminata* through the inhibition test of the enzyme 5-lipoxygenase (5-LOX), with an IC_{50} value of 60.36 µg/mL (Bose et al*.,* 2017). Inhibition of 5-LOX plays an important role in reducing the biosynthesis of leukotrienes that contribute to chronic inflammation, making this species a potential candidate for the development of natural anti-inflammatory agents. Some species also exhibit analgesic, sedative, and anxiolytic effects, as demonstrated by the tuber and root extracts of *Coelogyne suaveolens*. In the peripheral analgesic activity test using the acetic acid-induced writhing test, the tuber

extract showed an inhibition rate of 75.56%, while in the central test (tail immersion test), the reaction time increased by 32.13% (Eva et al*.,* 2024). Anxiolytic and sedative activities were obtained through the hole-board test and rotarod test, each with significant responses to the frequency of head dips and falling time at a dose of 400 mg/kg. These results indicate a central nervous system modulation effect, which is relevant in the development of phytotherapy for anxiety and pain disorders.

In addition, photoprotective activity has also been reported, especially in *Malaxis acuminata*, which showed a Sun Protection Factor (SPF) value of 29.0 at a concentration of 250 µg/mL (Bose et al., 2017). This value indicates the ability of the extract to absorb or reflect UV rays, so that it can act as a skin protective agent against free radical damage induced by ultraviolet light exposure. This activity opens up opportunities for application in the natural ingredient-based cosmetic industry, especially in the formulation of safe and environmentally friendly herbal sunscreens.

Although numerous *in vitro* bioactivities of orchid extracts have been reported, their translation into functional food applications remains limited. Key aspects such as bioavailability, metabolism, realistic dietary dosage, and long-term safety are rarely addressed. Direct extrapolation of *in vitro* efficacy to functional food claims should therefore be approached with caution. Further *in vivo* and food-matrix-based studies are required to support responsible functional food development.

5. Potential Orchid Plants as Functional Food

Functional food is a category of food products that additionally provide basic nutritional value, along with additional physiological benefits that can contribute to improving health and preventing disease (Essa et al., 2023). In recent decades, interest in natural ingredients as a source of bioactives for functional foods has increased along with the shift in people's consumption patterns towards natural-based products that are free from synthetic ingredients. In this context, phytochemical compounds found in orchids show great potential as candidates for active ingredients in the formulation of functional foods and nutraceutical products. Various secondary metabolite compounds identified from orchids, such as flavonoids, stilbenoids, phenolics, alkaloids, and terpenoids, have shown significant biological activities, including antioxidants, anti-inflammatory, antimicrobial, as well as potential as anticancer and immunomodulatory agents (Khan et al*.*, 2019; Rahman et al*.,* 2022).

The content of secondary metabolite compounds and their functions in orchid plants can potentially be applied to food products such as functional foods, nutraceuticals, supplements, and herbal and natural food additives (Ma et al*.,* 2021; Kiziltas et al*.,* 2022). As functional foods and nutraceuticals, formulations containing orchid extracts can be integrated into health drinks, cereals, fermented products, or herbal tablets. Several activities such as inhibition of digestive enzymes and anticancer potential that have been reported, open up opportunities for product development with specific health claims, in accordance with applicable food and traditional medicine regulations. As an example, the fruit part of *Vanilla planifolia* has been widely used in the food sector, one of which is as a flavor enhancer (Ramya et al*.,* 2020). In Shengji and Zhiwei, (2018), traditional processing of *Dendrobium* orchids is used as a composition in drinks and the stem is cooked with chicken or beef. In some regions like Turkey and Mediterranean region, the tuber of *Dactylorhiza* spp. has been used as a traditional hot drink called “salep”, which is also used as a mixture in making ice cream (Kotiloğlu et al*.,* 2020).

A critical challenge in developing orchid-based functional foods is the chemical instability of key bioactive compounds. Anthocyanins and other phenolic compounds are highly sensitive to heat, light exposure, oxygen, and pH variations commonly encountered during food processing and storage, leading to rapid degradation and loss of functionality (Khoo et al., 2017; Kumari et al., 2021). Moreover, interactions with complex food matrices may further affect compound stability and bioactivity, as observed in flower-derived phytochemicals applied in food systems (Nguyen et al., 2018). Therefore, formulation and processing strategies must be carefully designed to preserve bioactive integrity when orchid extracts are incorporated into functional foods. Furthermore, long-term safety data for orchid extracts are limited. Although some species have a history of traditional consumption, systematic chronic toxicity and safety evaluations are scarce. Further toxicological studies are needed before large-scale application in functional foods.

Further exploration of the stability, bioavailability, and safety of orchid extracts in complex food systems is an important step towards responsible and highly competitive commercialization in the global market. However, development challenges, especially related to aspects of bioavailability, interaction with food matrices, and long-term consumption safety need to be proven through *in vivo* approaches and controlled clinical studies. Thus, exploration of phytochemical compounds from orchids as basic ingredients for functional foods not only opens up opportunities for innovation in the food and health industries but can also provide added economic value to the horticulture and ornamental plant sectors. Many orchid species are rare or protected, raising ethical concerns regarding their use in industrial-scale functional food production. The future development of orchid-based functional foods must balance bioactive potential with conservation, regulatory compliance, and ethical sourcing practices.

6. Conclusions

The results of the review indicate that Orchidaceae species have diverse secondary metabolite contents such as phenolics, flavonoids, alkaloids, tannins, and anthocyanins, which show significant biological activities including antioxidant, antimicrobial, anticancer, antidiabetic, anti-inflammatory, and antiaging activities. These metabolites vary depending on the species, plant part, and extraction method and solvent used. Flowers and leaves are the most potential parts, with high compound concentrations and prominent biological activities in various *in vitro* tests. This study enriches the literature on the bioactivity of Orchidaceae and identifies a pattern that high levels of phenolics and flavonoids correlate with broad biological potential. In addition, the potential for inhibiting various enzymes such as collagenase, elastase, and α-glucosidase was found, strengthening the prospect of using orchids in functional food products and health supplements. This information is relevant for developers of phytopharmaceutical industry, natural antiaging products, and food innovations based on natural ingredients. However, this study is still limited by the lack of *in vivo* data, variations in extraction methodologies and activity tests, and limited clinical data. Therefore, further standardized studies are needed to evaluate the stability, bioavailability, and safety of compounds for the potential application in biological and food systems.

7. Acknowledgements

We would like to thank the library assistance from Univeristas Brawijaya, East Java, Indonesia for helped during writing.

8. Authors' Contributions

Syntiya Inanda Khoidir conceptualized the theme and wrote the manuscript. Deksa Aldebaran wrote the manuscript and assisted with article review. Nur Aniza Aprilia wrote the manuscript and helped to review the article. Dimas Setyadi Putra comprehensively revised and improved the quality of the manuscript. All authors have read and agreed to the published version of the manuscript.

ORCID
Dimas Setyadi Putra https://orcid.org/0000-0001-8176-4667
Syntiya Inanda Khoidir https://orcid.org/0009-0005-3353-5575
Deksa Aldebaran https://orcid.org/0009-0007-0135-8003
Nur Aniza Aprillia https://orcid.org/0009-0004-1038-4084

9. Conflicts of Interest

Authors declare that they have no known competing financial interests or non-financial interests or relationships.

References

Athipornchai, A., & Jullapo, N. (2018). Tyrosinase inhibitory and antioxidant activities of orchid (*Dendrobium* spp.). *South African Journal of Botany*, *119*, 188-192. https://doi.org/10.1016/j.sajb.2018.09.003

Barragán-Zarate, G. S., Lagunez-Rivera, L., Solano, R., Carranza-Álvarez, C., Hernández-Benavides, D. M., & Vilarem, G. (2022). Validation of the traditional medicinal use of a Mexican endemic orchid (*Prosthechea karwinskii*) through UPLC-ESI-qTOF-MS/MS characterization of its bioactive compounds. *Heliyon*, *8*(7), Article e09867. https://doi.org/10.1016/j.heliyon.2022.e09867

Bazzicalupo, M., Burlando, B., Denaro, M., Barreca, D., Trombetta, D., Smeriglio, A., & Cornara, L. (2019). Polyphenol characterization and skin-preserving properties of hydroalcoholic flower extract from *Himantoglossum robertianum* (Orchidaceae). *Plants*, *8*(11), Article 502. https://doi.org/10.3390/plants8110502

Bazzicalupo, M., Calevo, J., Smeriglio, A., & Cornara, L. (2023). Traditional, therapeutic uses and phytochemistry of terrestrial European orchids and implications for conservation. *Plants*, *12*(2), Article 257. https://doi.org/10.3390/plants12020257

Bhatnagar, M., Sarkar, N., Gandharv, N., Apang, O., Singh, S., & Ghosal, S. (2017). Evaluation of antimycobacterial, leishmanicidal and antibacterial activity of three medicinal orchids of Arunachal Pradesh, India. *BMC Complementary and Alternative Medicine*, *17*(1), Article 379. https://doi.org/10.1186/s12906-017-1884-z

Bhattacharyya, P., Kumaria, S., Job, N., & Tandon, P. (2015). Phyto-molecular profiling and assessment of antioxidant activity within micropropagated plants of *Dendrobium thyrsiflorum*: a threatened, medicinal orchid. *Plant Cell, Tissue and Organ Culture*, *122*(3), 535-550. https://doi.org/10.1007/s11240-015-0783-6

Bose, B., Choudhury, H., Tandon, P., & Kumaria, S. (2017). Studies on secondary metabolite profiling, anti-inflammatory potential, in vitro photoprotective and skin-aging related enzyme inhibitory activities of *Malaxis acuminata*, a threatened orchid of nutraceutical importance. *Journal of Photochemistry and Photobiology B: Biology*,

173, 686-695. https://doi.org/10.1016/j.jphotobiol.2017.07.010

Casciaro, B., Calcaterra, A., Cappiello, F., Mori, M., Loffredo, M. R., Ghirga, F., Mangoni, M. L., Botta, B., & Quaglio, D. (2019). Nigritanine as a new potential antimicrobial alkaloid for the treatment of *Staphylococcus aureus*-induced infections. *Toxins*, *11*(9), Article 511. https://doi.org/10.3390/toxins11090511

De, L. (2022). Chemical ingredients of important 75 medicinal orchids. *International Journal of Chemistry Studies*, *6*(1), 73-79.

Essa, M. M., Bishir, M., Bhat, A., Chidambaram, S. B., Al-Balushi, B., Hamdan, H., Govindarajan, N., Freidland, R. P., & Qoronfleh, M. W. (2023). Functional foods and their impact on health. *Journal of Food Science and Technology*, *60*(3), 820-834. https://doi.org/10.1007/s13197-021-05193-3

Eva, T. A., Mamurat, H., Rahat, M. H. H., & Hossen, S. M. M. (2024). Unveiling the pharmacological potential of *Coelogyne suaveolens*: An investigation of its diverse pharmacological activities by in vivo and computational studies. *Food Science and Nutrition*, *12*(3), 1749-1767. https://doi.org/10.1002/fsn3.3867

Gantait, S., Das, A., Mitra, M., & Chen, J.-T. (2021). Secondary metabolites in orchids: Biosynthesis, medicinal uses, and biotechnology. *South African Journal of Botany*, *139*, 338-351. https://doi.org/10.1016/j.sajb.2021.03.015

Hossen, S. M. M., Eva, T. A., Karim, M. S., Mamurat, H., Rahat, M. H. H., & Nipun, T. S. (2024). Antimicrobial potential, GCMS analysis and molecular docking studies of *Coelogyne suaveolens* extracts: Identification of bioactive compounds with mechanism of action. *Biochemistry and Biophysics Reports*, *37*, Article 101648. https://doi.org/10.1016/j.bbrep.2024.101648

Hu, Y., Zhang, C., Zhao, X., Wang, Y., Feng, D., Zhang, M., & Xie, H. (2016). (±)-Homocrepidine A, a pair of anti-inflammatory enantiomeric octahydroindolizine alkaloid dimers from *Dendrobium crepidatum*. *Journal of Natural Products*, *79*(1), 252-256. https://doi.org/10.1021/acs.jnatprod.5b00801

Kanlayavattanakul, M., Lourith, N., & Chaikul, P. (2018). Biological activity and phytochemical profiles of *Dendrobium*: A new source for specialty cosmetic materials. *Industrial Crops and Products*, *120*, 61-70. https://doi.org/10.1016/j.indcrop.2018.04.059

Khan, H., Marya, Belwal, T., Tariq, M., Atanasov, A. G., & Devkota, H. P. (2019). Genus Vanda: A review on traditional uses, bioactive chemical constituents and pharmacological activities. *Journal of Ethnopharmacology*, *229*, 46-53. https://doi.org/10.1016/j.jep.2018.09.031

Khoo, H. E., Azlan, A., Tang, S. T., & Lim, S. M. (2017). Anthocyanidins and anthocyanins: Colored pigments as food, pharmaceutical ingredients, and the potential health benefits. *Food and Nutrition Research*, *61*, Article 1361779. https://doi.org/10.1080/16546628.2017.1361779

Kiziltas, H., Goren, A. C., Alwasel, S. H., & Gulcin, İ. (2022). Sahlep (*Dactylorhiza osmanica*): Phytochemical analyses by LC-HRMS, molecular docking, antioxidant activity, and enzyme inhibition profiles. *Molecules*, *27*(20), Article 6907. https://doi.org/10.3390/molecules27206907

Kotiloğlu, D., Acet, T., & Özcan, K. (2020). Phytochemical profile and biological activity of a therapeutic orchid from Anatolia: *Dactylorhiza romana* subsp. *georgica*. *Journal of Food Measurement and Characterization*, *14*(6), 3310-3318. https://doi.org/10.1007/s11694-020-00566-2

Kumar, A., Mahanty, B., Goswami, R. C. D., Barooah, P. K., & Choudhury, B. (2021). In vitro antidiabetic, antioxidant activities and GC–MS analysis of *Rhynchostylis Retusa* and *Euphorbia Neriifolia* leaf extracts. *3 Biotech*, *11*(7), Article 315. https://doi.org/10.1007/s13205-021-02869-7

Kumari, P., Ujala, & Bhargava, B. (2021). Phytochemicals from edible flowers: Opening a new arena for healthy lifestyle. *Journal of Functional Foods*, *78*, Article 104375.

https://doi.org/10.1016/j.jff.2021.104375
Ma, J., Deng, Y., Wang, Y., Liu, Q., An, J., Li, M., Song, N., Zhang, J., Cheng, L., & Ma, K. (2021). A comparative study on ingredient and efficiency difference between fresh and steamed *Gastrodia elata* Blume: An herbal material to a novel functional food. *Journal of Functional Foods*, *82*, Article 104512. https://doi.org/10.1016/j.jff.2021.104512
Mahomoodally, M. F., Picot-Allain, M. C. N., Zengin, G., Llorent-Martínez, E. J., Abdullah, H. H., Ak, G., Senkardes, I., Chiavaroli, A., Menghini, L., Recinella, L., Brunetti, L., Leone, S., Orlando, G., & Ferrante, C. (2020). Phytochemical analysis, network pharmacology and in silico investigations on *Anacamptis pyramidalis* tuber extracts. *Molecules*, *25*(10), Article 2422. https://doi.org/10.3390/molecules25102422
Misra, A., Chaudhary, M. K., Tripathi, D., Srivastava, P. K., Gupta, V., Acharya, R., & Srivastava, S. (2023). Nutritional potential of an edible terrestrial orchid *Eulophia nuda* LINDL and validation of its traditional claim in arthritis. *Journal of Ethnopharmacology*, *306*, Article 116123. https://doi.org/10.1016/j.jep.2022.116123
Natta, S., Mondol, M. S. A., Pal, K., Mandal, S., Sahana, N., Pal, R., Pandit, G. K., Alam, B. K., Das, S. S., Biswas, S. S., & NS, K. (2022). Chemical composition, antioxidant activity and bioactive constituents of six native endangered medicinal orchid species from north-eastern Himalayan region of India. *South African Journal of Botany*, *150*, 248-259. https://doi.org/10.1016/j.sajb.2022.07.020
Nguyen, H. C., Lin, K.-H., Huang, M. Y., Yang, C. M., Shih, T. H., Hsiung, T.-C., Lin, Y.-C., & Tsao, F.-C. (2018). Antioxidant activities of the methanol extracts of various parts of Phalaenopsis orchids with white, yellow, and purple flowers. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *46*(2), 457-465. https://doi.org/10.15835/nbha46211038
Obsuwan, K., Ryong, J. B., & Maksup, S. (2019). Analysis of bioactive compounds, polysaccharides and antioxidant activity in different parts of *Dendrobium* "Sonia Jo Daeng." *Science, Engineering and Health Studies*, *13*(2), 73-82.
Padhee, S., Mohanty, D., Kerry, R. G., Das, P. K., Jena, S., Sahoo, A., Panda, P. C., Mohanty, S., Ray, A., Khan, H. A., & Nayak, S. (2025). Ultra-performance liquid chromatography coupled with quadrupole time-of-flight mass spectrometry-based profiling and evaluation of antioxidant, antityrosinase, antimicrobial and antiproliferative activities of *Eulophia nuda* Lindl.: A medicinal orchid. *Chemistry and Biodiversity*, *22*(8), Article e202402833. https://doi.org/10.1002/cbdv.202402833
Parveen, S., Ramesh, C. K., Mahmood, R., & Pallavi, M. (2018). Folklore medicinal orchids from south india: The potential source of antioxidants. *Asian Journal of Pharmaceutical and Clinical Research*, *11*(6), 194-198. https://doi.org/10.22159/ajpcr.2018.v11i6.24726
Pathak, P., Kumari, A., Chandler, B. D., & Zettler, L. W. (2023). In vitro propagation and phytochemical analysis of *Vanda cristata* Wall. ex Lindl: An endangered medicinal orchid of biopharmaceutical importance. *South African Journal of Botany*, *153*, 109-123. https://doi.org/10.1016/j.sajb.2022.11.023
Paudel, M. R., Chand, M. B., Pant, B., & Pant, B. (2018). Antioxidant and cytotoxic activities of *Dendrobium moniliforme* extracts and the detection of related compounds by GC-MS. *BMC Complementary and Alternative Medicine*, *18*(1), Article 134. https://doi.org/10.1186/s12906-018-2197-6
Paudel, M. R., Chand, M. B., Pant, B., & Pant, B. (2019). Assessment of antioxidant and cytotoxic activities of extracts of *Dendrobium crepidatum*. *Biomolecules*, *9*(9), Article 478. https://doi.org/10.3390/biom9090478
Perkins, J., Hayashi, T., Peakall, R., Flematti, G. R., & Bohman, B. (2023). The volatile chemistry of orchid pollination. *Natural Product Reports*, *40*(4), 819-839. https://doi.org/10.1039/d2np00060a
Rahamtulla, M., Mallikarjuna, K., & Khasim, S. M. (2023). GC-MS analysis and therapeutic

importance of leaf extracts of *Dendrobium aphyllum* (Roxb.) C.E.C. Fischer: An *in vitro* study. *South African Journal of Botany*, *153*, 62-76. https://doi.org/10.1016/j.sajb.2022.12.011

Rahman, M., Surag, A. T., Begum, R., Tusher, M. S. H., & Huda, M. K. (2022). Phytochemical, antioxidant, anti-inflammatory, and thrombolytic properties of *Cleisomeria lanatum* (Lindl.) Lindl. ex G. Don. *Scientifica*, *2022*(1), Article 5660527 https://doi.org/10.1155/2022/5660527

Ramya, M., Jang, S., An, H.-R., Lee, S.-Y., Park, P.-M., & Park, P. H. (2020). Volatile organic compounds from orchids: From synthesis and function to gene regulation. *International Journal of Molecular Sciences*, *21*(3), Article 1160. https://doi.org/10.3390/ijms21031160

Roy, A., Khan, A., Ahmad, I., Alghamdi, S., Rajab, B. S., Babalghith, A. O., Alshahrani, M. Y., Islam, S., & Islam, M. R. (2022). Flavonoids a bioactive compound from medicinal plants and its therapeutic applications. *BioMed Research International*, *2022*(1), Article 5445291. https://doi.org/10.1155/2022/5445291

Sein, K. L., Lertnitikul, N., Suttisri, R., & Jianmongkol, S. (2023). Anticancer and chemosensitizing activities of stilbenoids from three orchid species. *Naunyn-Schmiedeberg's Archives of Pharmacology*, *396*(4), 749-758. https://doi.org/10.1007/s00210-022-02352-x

Shengji, P., & Zhiwei, Y. (2018). Orchids and its uses in chinese Chinese medicine and health care products. *Medical Research and Innovations*, *2*(1), 1-3. https://doi.org/10.15761/mri.1000133

Shukla, M. K., Monika, Thakur, A., Verma, R., Lalhlenmawia, H., Bhattacharyya, S., Bisht, D., Singh, A., Parcha, V., & Kumar, D. (2022). Unravelling the therapeutic potential of orchid plant against cancer. *South African Journal of Botany*, *150*, 69-79. https://doi.org/10.1016/j.sajb.2022.07.005

Sukumaran, N. P., & Yadav, R. H. (2016). General unknown screening, antioxidant and anti-inflammatory potential of *Dendrobium macrostachyum* Lindl. *Ancient Science of Life*, *35*(4), 240-244. https://doi.org/10.4103/0257-7941.188181

Suphrom, N., Pipatsawasdikul, K., Kongbangkerd, A., Chikun, K., Ngobkhonburi, S., Muaklek, B., Pitsamai, W., Nisaipham, B., Chuaimueang, W., Sasiri, P., Khongwet, S., Tothong, C., Pankaew, C., Insumrong, K., & Limmongkon, A. (2024). Bioactivity assay of *Arundina graminifolia* (D.Don) Hochr. extracts from diverse plant parts in Thailand: An assay-based investigation. *Scientia Horticulturae*, *327*, Article 112876. https://doi.org/10.1016/j.scienta.2024.112876

Swainson, N. M., Pengoan, T., Khonsap, R., Meksangsee, P., Hagn, G., Gerner, C., & Aramrak, A. (2023). *In vitro* inhibitory effects on free radicals, pigmentation, and skin cancer cell proliferation from *Dendrobium* hybrid extract: A new plant source of active compounds. *Heliyon*, *9*(9), Article e20197. https://doi.org/10.1016/j.heliyon.2023.e20197

Wati, R. K., Astuti, I. P., & Cahyaningsih, R. (2023). Inventorying medicinal orchid in Indonesia from global database. *E3S Web of Conferences*, *373*, Article 05009. https://doi.org/10.1051/e3sconf/202337305009

Zhang, G.-Q., Liu, K.-W., Li, Z., Lohaus, R., Hsiao, Y.-Y., Niu, S.-C., Wang, J.-Y., Lin, Y.-C., Xu, Q., Chen, L.-J., Yoshida, K., Fujiwara, S., Wang, Z.-W., Zhang, Y.-Q., Mitsuda, N., Wang, M., Liu, G.-H., Pecoraro, L., Huang, H.-X., Xiao, X.-J., … Liu, Z.-J. (2017). The Apostasia genome and the evolution of orchids. *Nature*, *549*(7672), 379-383. https://doi.org/10.1038/nature23897

Zhou, Z., Ying, Z., Wu, Z., Yang, Y., Fu, S., Xu, W., Yao, L., Zeng, A., Huang, J., Lan, S., Wang, X., & Liu, Z. (2021). Anthocyanin genes involved in the flower coloration mechanisms of *Cymbidium kanran*. *Frontiers in Plant Science*, *12*, Article 737815. https://doi.org/10.3389/fpls.2021.737815