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A critical review on the multidimensional utility of Orchidaceae in medicine, food and cosmetics

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Abstract

Orchids, traditionally prized for their ornamental value, are increasingly recognised for their multifaceted applications in medicine, food and cosmetics. Beyond their aesthetic appeal, orchids possess significant pharmaceutical, nutraceutical and therapeutic potential due to their diverse repertoire of bioactive compounds. They also contribute to the fragrance and cosmetic industries, support biodiversity conservation and offer substantial economic opportunities through commercial cultivation and value-added products. Although several reviews have focused on the medicinal or phytochemical aspects of orchids, a comprehensive evaluation integrating their pharmaceutical, nutraceutical, food and cosmeceutical potential remain limited. This critical review provides a multidisciplinary perspective by consolidating current knowledge on the therapeutic, nutritional and cosmetic applications of Orchidaceae. Particular attention is given to the biochemical and phytochemical composition of orchids, including alkaloids, flavonoids, terpenoids, bibenzyls, phenanthrenes and other polyphenolic compounds. These bioactive constituents underpin a wide spectrum of biological activities such as antimicrobial, antioxidant, anti-inflammatory and immunomodulatory effects, thereby supporting their relevance in health-promoting applications. The review further identifies key orchid genera and species with promising potential across different application domains, providing a framework for targeted utilisation and research. Overall, this work highlights the underexplored potential of orchids as sustainable, high-value bioresources. It underscores the need for systematic research, conservation strategies and standardisation of orchid-derived bioactive extracts to facilitate their integration into pharmaceutical, nutraceutical and cosmeceutical industries.

Keywords: biochemical properties; cosmetic applications; medicinal use; multipurpose crop; nutritional use; orchids

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1. Introduction

The family Orchidaceae is one of the largest and most diverse of the angiosperms, with about 28000–30000 species in over 760 genera across the world (1). This remarkable diversity is also evident in their habitat, which ranges from the tropical to temperate forests, with the highest species diversity found in tropical forests (2). Apart from their ecological significance, orchids also have significant economic value, especially in the international floriculture industry, where orchids are highly valued for their aesthetic value and long-lasting blooms (3). Orchids are not only ornamental plants but also significant biological resources that have gained scientific interest in recent years due to their wide-ranging applications in various industries (4).

Orchids are known for their ability to produce a diverse range of compounds, such as alkaloids, flavonoids, phenanthrenes, terpenoids, stilbenoids and phenolic derivatives, many of which possess strong biological activities (5). These secondary metabolites include alkaloids, flavonoids, phenanthrenes, bibenzyl derivatives, terpenoids and polysaccharides, which have strong pharmacological activities such as antioxidant, anticancer, antidiabetic and neuroprotective properties (6). Moreover, metabolites found in orchids have exhibited noteworthy anti-inflammatory and antimicrobial properties, making them potential candidates for the

treatment of inflammatory diseases and infections (7). Furthermore, some species of terrestrial orchids *Orchis mascula* (L.) L., *Orchis militaris* L. and *Anacamptis morio* (L.) R.M.Bateman, Pridgeon & M.W.Chase give rise to nutrient-rich tubers, which are used as traditional and functional foods in select regions (8). Over the last few years, orchid extracts have also been increasingly used in the cosmetic and cosmeceutical industries for their antioxidant, anti-aging and skin-protective effects (9).

Moreover, there is a lack of integrative analyses in the existing literature that correlate the phytochemical properties with the use of the plant in various industries, thereby limiting the cross-sector utilisation of their bioactive potential (10). Though there is increasing knowledge about the various medicinal and industrial applications of orchids, there is a lack of a holistic and comprehensive understanding of the multifaceted potential of orchids (11). In this context, the present review provides a comprehensive overview of the phytochemistry, pharmacology and industrial applications of Orchidaceae within the plant kingdom, with special emphasis on their applications in medicine, food and cosmetics. Moreover, it addresses the therapeutic potential of the plant, while identifying research gaps and future research directions.

Previous reviews focused on individual aspects of orchids, lacking an integrated perspective. However, these reviews have largely focused on individual domains, leaving a lack of an integrated assessment of Orchidaceae across multiple sectors. Table 1 summarises existing reviews and knowledge gaps.

Scope of the review

The literature included in this narrative review was gathered from Scopus, Web of Science, PubMed, Google Scholar and ScienceDirect. Peer-reviewed studies published mainly between 2000 and 2026 were examined, with greater emphasis on recent publications. Studies were selected based on their relevance to the medicinal, food, cosmetic, phytochemical and ethnobotanical applications of orchids.

Table 1. Overview of published reviews on Orchidaceae and research gaps addressed in the present review

Previous review	Unresolved gap	How the present review addresses the gap	Reference
Ethnobotany, phytochemistry, pharmacology and conservation of the genus *Calanthe*.	Restricted to a single genus; findings cannot be generalised across Orchidaceae. Limited discussion of food and cosmetics.	Synthesises information across numerous orchid genera and compares their phytochemicals, pharmacological activities, edible uses and cosmetic potential.	(12)
Therapeutic orchids: Traditional uses and recent advances-An overview.	Primarily focused on medicinal applications; limited discussion of phytochemical activity relationships, food uses and cosmetic applications.	Provides an integrated evaluation of orchid phytochemicals and links them with medicinal, food, cosmetic and economic applications while highlighting future industrial prospects.	(13)
A comprehensive review of the cosmeceutical benefits of *Vanda* species (Orchidaceae).	Restricted to *Vanda* species and cosmetic applications only. Does not compare other orchid genera or integrate medicinal, food and phytochemical evidence.	Reviews multiple orchid genera and correlates phytochemicals with medicinal, food, cosmetic and industrial applications in a single framework.	(14)
The budding potential of orchids in the cosmeceutical sector: role of orchids in skincare and health.	Focuses mainly on skincare; limited discussion of phytochemical diversity, edible orchids, pharmacology and commercialisation.	Integrates cosmetic applications with phytochemistry, pharmacology, food uses, economic value and future commercialisation opportunities.	(15)
Phytochemical study of Orchidaceae: Composition, bioactivity and potential application in functional foods.	Concentrates on functional foods. Economic importance and commercialisation is not comprehensively addressed.	Broadens the scope by integrating phytochemistry, medicinal uses, food applications, cosmetic potential and future industrial utilisation.	(16)

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Medicinal applications of orchids

Significance of orchids in ethnomedicine

Orchids belong to the family Orchidaceae and their ethnomedicinal significance has been documented extensively across tribal and indigenous communities worldwide (17). Several Indian tribes have long utilised orchids to treat scorpion and snake bites, leucoderma, eczema, tumours, diarrhoea, earache, sexually transmitted diseases, dysentery, paralysis, cholera, wounds, arthritis, bone fractures, spermatorrhoea, muscular pains and asthma, with rhizomes, tubers, roots and leaves serving as the primary plant parts used in traditional preparations (18). In the Western Himalayas of Azad Jammu and Kashmir, ethnobotanical field surveys documented 21 orchid species used by local communities for digestive disorders, liver diseases, gout, urinary tract infections, skin diseases, tuberculosis and diabetes, with *Dactylorhiza hatagirea* (D.Don) Soó recording the highest fidelity level of 68.75 %, affirming the specificity of traditional orchid knowledge in these mountain communities (19). The most frequently reported pharmacological activities among the 62 medicinal orchid species utilised by indigenous communities in Mexico include anti-inflammatory, vasorelaxant, antinociceptive, antioxidant, spasmolytic, antihypertensive and hallucinogenic properties. Nevertheless, 77 % of these species are still ethnomedically documented but have not been scientifically validated, indicating a sizable and largely untapped reservoir for future pharmacological research (11). Species such as *Dendrobium nobile* Lindl. and *Vanda tessellata* (Roxb.) Hook. ex G.Don are traditionally utilised in Ayurveda and traditional Chinese medicine to address respiratory ailments, skin conditions and reproductive health concerns, with biological activities linked to more than 214 orchid species across 64 genera that contain alkaloids, flavonoids, phenanthrenes, terpenoids and bibenzyl derivatives that hold potential therapeutic benefits (20). The following table presents the summary of orchid species, plant parts used, traditional indications and supporting references to improve its utility in ethnomedicine (Table 2).

Orchids in traditional medicine systems

Use of orchids in Ayurveda systems

The medicinal use of orchids constitutes an important and long-standing component of Indian ethnobotanical knowledge, with references to their therapeutic applications dating back to the Vedic period (2000–600 B.C.) (21). Orchidaceae is a large family of flowering plants which constitute about 8–10 % of all flowering plants in the world and play an important role in classical ayurvedic therapeutics (22). In addition to the Ashtavarga, orchids like Flickingeria macraei (known in Ayurveda as jeevanti) are listed as astringents, aphrodisiacs and anti-asthmatics. Moreover, the underground tuber of *Orchis latifolia* L. is described as the ingredient used to make the cough remedy munjataka as spelled out in the *Susruta Samhita* (23). The use of orchids in Ayurveda extends over a wide spectrum of ailments, where practitioners use various parts of the plants such as tubers, pseudobulbs, rhizomes and whole plants to make taila (medicated oil), ghrita (clarified butter), churna (powder) and lehya (electuary). The Ashtavarga orchid group that is used in combination with complementary plants are prescribed in order to enhance body fat, fracture curing, seminal weakness, fever and even for the treatment of diabetes.

These plants are also used to harmonize the three doshas including Vata, Pitta and Kapha (24). An ethnobotanical study of the Himalayan Botanical Garden also identified 24 species of Orchids in 15 genera, of which 67 % showed ethnomedicinal relevance and *Malaxis muscifera* (Lindl.) Kuntze and *Habenaria intermedia* D.Don were confirmed as canonical Ashtavarga plants used for systemic rejuvenation and immunity (25).

Use of orchids in Chinese medicine

Gastrodia elata Blume*, Dendrobium officinale* Kimura & Migo*, D. nobile, Dendrobium chrysotoxum* Lindl. and *Bletilla striata* (Thunb.) Rchb.f. are the most important medicinal species used in traditional Chinese medicine (TCM) and are included in the China Pharmacopoeia (26). In recent years, phytochemicals of medicinal orchids have been studied and 155 new secondary metabolites have been identified, such as 27 alkaloids, 39 phenanthrenes, 35 bibenzyls and 54 other compounds, highlighting the growing pharmacological significance of Orchidaceae (27). Moscatilin was isolated from *D. nobile*, a bibenzyl compound that demonstrated potent cytotoxic activity against human tongue squamous carcinoma cells (OSC-19) with an IC_{50} value of 1.32 μM, while simultaneously suppressing cell migration via downregulation of MMP2 and MMP9 at concentrations of 0.5–1 μM (28). Similarly, *B. striata* contains diverse bioactive phytochemical classes among which polysaccharides are considered major constituents associated with its hemostatic, wound-healing, anti-inflammatory and immunomodulatory effects. In addition, non-polysaccharide constituents like bibenzyls, phenanthrenes and phenolic compounds contribute to antioxidant, antimicrobial and antitumour activities (29).

Phytochemical properties of orchids in medicine

Antioxidant properties of orchids

The antioxidant activity of Orchidaceae is highly species-specific, with *Dendrobium spp*. have been demonstrated to be the most potent by their ability to directly neutralise reactive oxygen species (ROS) and regulate redox homeostasis through high accumulation of phenolics, flavonoids and polysaccharides (30).

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Table 2. Ethnomedicinal applications of orchid species reported in traditional medicine systems, indicating their medicinal uses and plant parts

Sl. No.	Orchid species	Ethnomedicinal uses	Plant part used
1	Goodyera repens (Lindl.)	Used as blood purifier	Root/leaves
2	*Flickingeria macraei* (Lindl.) Seidenf.	Used to treat skin allergy and eczema.	Root
3	Bulbophyllm umbellatum	Used in congenital diseases	Whole plant
4	*Calanthe sylvatica* (Thouars) Lindl.	To treat nasal bleeding	Flower/fruits/seeds
5	*Nervilia aragoana* Gaudich.	Used to treat urinary tract diseases, asthma and vomiting	Whole plant
6	Eria muscicola	Used to treat heart disease, lungs, eye, ears and nervous system	Whole plant
7	*Cymbidium devonianum* Paxton	Used to treat cough and cold	Whole plant
8.	*Flickingeria fugax* (Rchb.f.) Seidenf.	Used as tonic.	Whole plant
9	*Dendrobium eriifolium* Griff.	For treating fractured and dislocated bones	Stem/pseudobulb
10	Eulophia dabia	Used in the treatment of cough and cold	Tubers
11	*Acampe carinata* (Griff.)	Snake bites, stomach disorder and acidity.	Roots
12	*Habenaria commelinifolia*.	As salep in combination with other orchids.	Root
13	*Aerides multiflora* Roxb.	For treating cuts and wounds. Fruit is used for healing wounds.	Leaves/stem/ pseudobulb
14	*Rhynchostylis retusa*	Rheumatic disease, wounds, asthma, tuberculosis, nervous twitching, cramps, kidney stone and menstrual disorders.	Root/whole plant
15	Dendrobium hatagirea	Used for anti-Inflammatory activity, antipyretic activity and sedative.	Root, flower
16	*Papilionanthe teres* (Roxb.) Schltr	Used in ear infection, nose bleeding and pyrexia	Leaves, stem/pseudobulb, whole plant
17	Vanda roxburghii.	Antipyretic, otitis media. The roots are used in rheumatism, acid peptic diseases, sciatica.	Leaf, roots
18	*Cymbidium goeringii* (Rchb.f.)	Whole Plant Used as diuretic and hypotensive, activities.	Whole plant
19	*Spathoglottis plicata* Blume	It is used to treat rheumatic disease.	Leaves
20	*Zeuxine longilabris* (Lindl.) Trimen	In cough and cold.	Whole plant
21	*Geodorum recurvum* (Roxb.)	Suppress tumours	Stem
22	*Malaxis acuminata* D.Don	As a coagulant, diathesis, burning sensation in stomach, pyrexia and arthritis.	Stem/pseudobulb
23	*Luisia zeylanica* Lindl.	Used to treat wounds, boils and burns.	Leaves
24	*Bulbophyllum careyanum* (Hook.) Spreng	When mixed with honey, used in abortion in early months. In burns, wounds and recovery in case of child birth	Leaves, stem/ pseudobulb
25	*Geodorum densiflorum* (Lam.) Schltr	Used for treating wounds and insect bite	Root

Furthermore, the high level of flavonoids, tannins and quercetin in several orchid species of the Himalayan region such as *Dendrobium densiflorum* Lindl. and *Coelogyne nitida* (Wall. ex Lindl.) Lindl. has been observed to possess a high antioxidant capacity (31). Importantly, antioxidant agents in *D. nobile* have shown their neuroprotective effects, such as reducing oxidative damage to neurons in neurodegenerative diseases like Alzheimer's disease, suggesting their potential for wider medicinal applications (32). The antioxidant activity of methanolic extracts from different plant parts of white, yellow and purple coloured *Phalaenopsis* orchids using the DPPH radical-scavenging assay and found that antioxidant activity varied among orchid flower colours and plant parts. The authors reported a positive association between pigment composition and antioxidant activity, particularly with flavonoids and anthocyanins, suggesting that differences in antioxidant capacity among orchid types and plant parts may be related to variations in their phytochemical composition and flower pigmentation (33).

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Anti-inflammatory properties of orchids

Orchids, especially the species of *Dendrobium* have been well reported to have considerable anti-inflammatory effects because of the existence of a wide range of bioactive substances like polysaccharides, alkaloids, flavonoids, bibenzyls and phenolic compounds which exert various actions on several inflammatory pathways and show multi-target therapeutic potential in inflammatory diseases (34). In *Dendrobium huoshanense* C.Z.Tang & S.J.Cheng, the ethanol extract of stems significantly suppressed lipopolysaccharide (LPS)-induced nitric oxide, TNF-α and IL-1β production in RAW 264.7 macrophages. Moreover, bioassay-guided fractionation identified anti-inflammatory bibenzyls from the active extract (35). Anti-inflammatory activity of orchids has been found to be highly species-specific with *D. officinale* being one of the most potent taxa because of its rich bioactive profile of flavonoids and polysaccharides, of which *in vivo* activity-guided metabolomics revealed over 3700 metabolites and selected five important anti-inflammatory compounds, with isovitexin notably reducing the severity of ulcerative colitis by inhibiting the PI3K/AKT pathway (36) (Fig. 1).

Antimicrobial properties of orchids

Recent studies reveal that Orchidaceae exhibit notable antimicrobial and antifungal properties, especially in genera like *Dendrobium*, *Aerides*, *Cymbidium* and *Coelogyne*, where their secondary metabolites, such as phenolics, flavonoids, bibenzyl derivatives and alkaloids, are responsible for a wide-ranging inhibitory activity against pathogenic microorganisms (37). Extraction solvent similarly influences antimicrobial efficacy. Methanolic extracts of the stem, root and pseudobulb of *Dendrobium crumenatum* Sw. showed antimicrobial activity against several pathogenic bacteria, with the stem extract exhibiting particularly strong activity against *Staphylococcus aureus*, *Klebsiella pneumoniae* and *Enterobacter aerogenes* (38). Of these, *Aerides multiflora* shows high activity against *S. aureus, Escherichia coli, Aspergillus niger* and *Fusarium oxysporum* with inhibition zones of 18–25 mm and minimum inhibitory concentration (MIC) values ranging from 0.25–1.0 mg mL^{-1}, which validates its traditional utilisation in the treatment of skin infections, wound contamination and fungal dermatitis (39). The quantitative phytochemical analysis also shows that *Dendrobium linearifolium* Teijsm. & Binn. (total phenolic content approximately 374.47 mg GAE g^{-1}) exhibits significant antibacterial activity against Gram-positive bacteria, which is consistent with its use for treating localised infections and microbial conditions associated with inflammation (40). The following table presents a summary of the antimicrobial properties of orchids (Table 3).

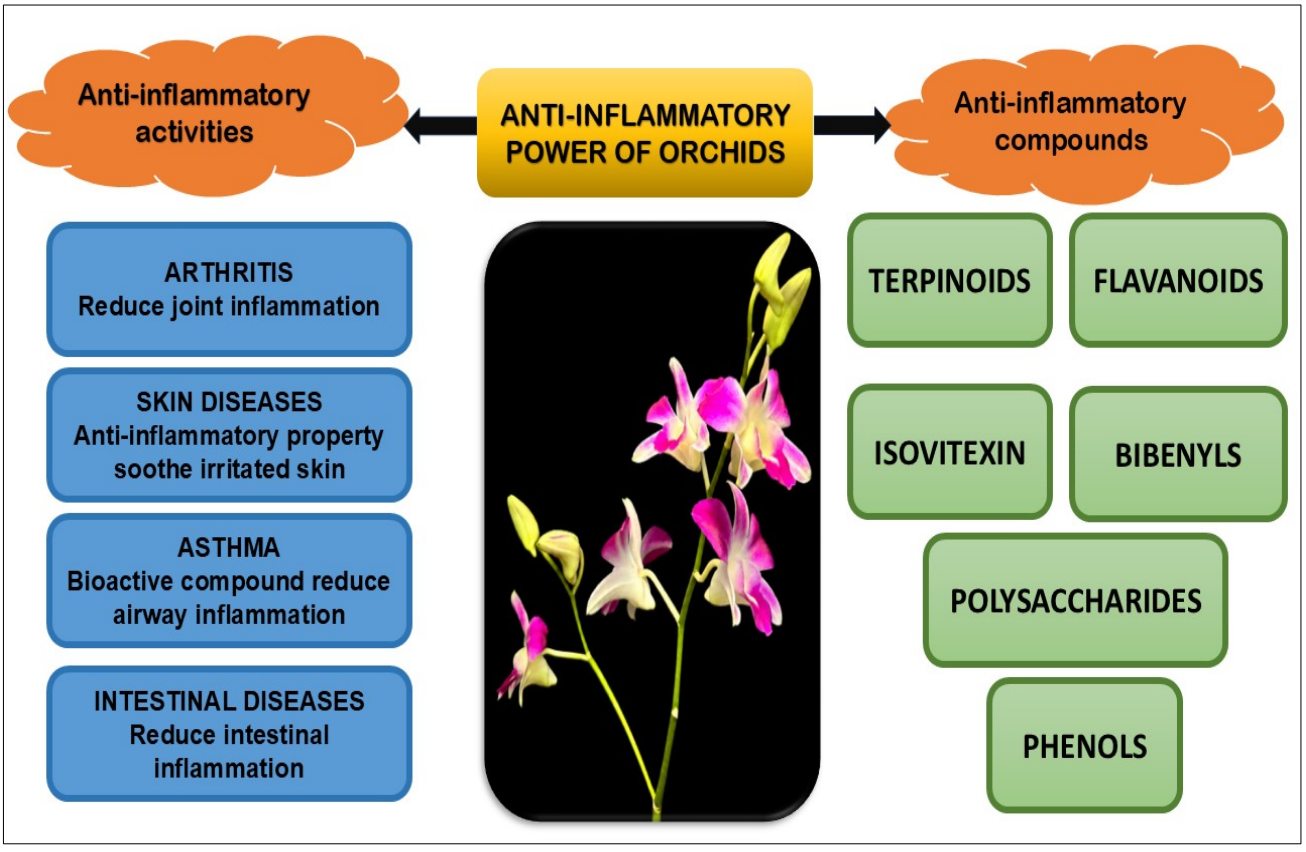


Fig. 1. Anti-inflammatory property of orchids.

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Table 3. Compilation of the antimicrobial properties of orchid, illustrating the association between the plant parts used, bioactive compounds, target microorganisms and mechanisms of action

Orchid	Parts used	Bioactive compound	Target microorganism	Mode of action
Gastrodia elata	Whole plant	Gastrodianin	fungi	*In vitro* antifungal activity. This establishes the gastrodianin-like proteins (GLIPs) as a novel class of antifungal proteins.
Spiranthus mauritianus	Leaves	methanol	Gram-positive bacteria	It has been used to inhibit bacteria growth.
Galeola foliate	Leaves and stem bark	methylene chloride	Gram positive and Gram-negative bacteria	Anti-bacterial activity.
Vanilla planifolia	Whole plant	Vanillin	*Escherichia coli, Lactobacillus plantarum* and *Listeria innocua*	It has managed to inhibit the respiration of these microbes and by disrupting ion channel gradients and dissipating potassium ion influx, thereby inhibiting respiration
Cypripedium macranthos	Seedlings	Ethanol from the plantlets	Anti-fungal	This was shown to have an inhibition in the growth of fungus, ethyl acetate (EtOAc) is found out to be able to bind to the ergosterol synthesis of the fungi cell wall and inhibiting its growth.

Anticancer properties of orchid

The anti-cancer properties of orchids has attracted much scientific research and over 145 orchid species are recorded from Northeast India and widely utilised for cancer, with various tumours and cancerous illnesses (41). Methanol extraction of *Dendrobium brymerianum* Rchb.f. also enabled isolation of phenolic compounds, including moscatilin and gigantol, which exhibited cytotoxic activity against human lung cancer cells (42). Similarly, *Cremastra appendiculata* (D.Don) Makino has been reported to yield phenanthrene derivatives exhibiting moderate cytotoxicity against at least six cancer types including colon (HCT-8), hepatoma (Bel-7402), lung (A549), breast (MCF-7), ovarian (A2780) and gastric cancers, indicating multi-target efficacy (43). In line with these results, *Dienia ophrydis* (J.Koenig) Seidenf. was found to exhibit considerable anticancer activity with IC_{50} values ranging from 43.08–58.2 µg/mL against human breast cancer (MCF-7); this quantitatively supports its therapeutic potential (44). The figure provides the molecular pathways for various properties of orchids (Fig. 2).

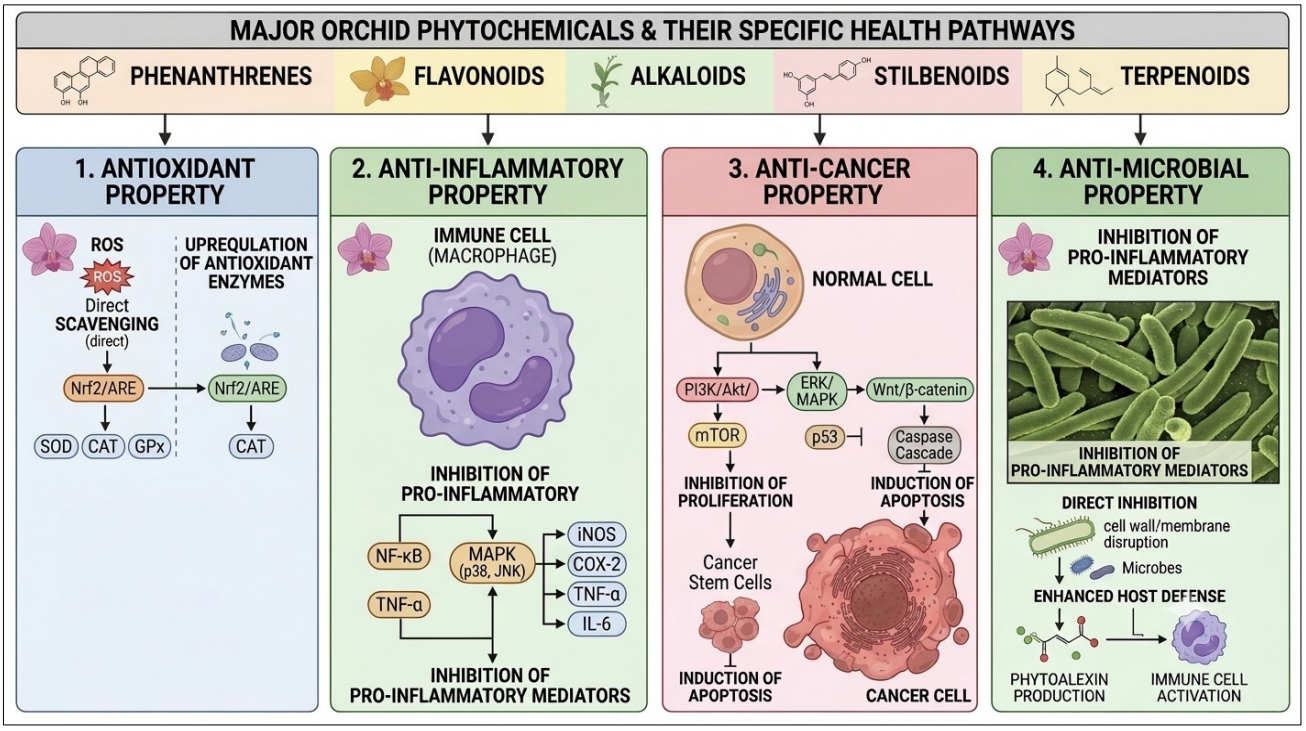


Fig. 2. A schematic illustration of orchid phytochemicals interaction with signalling pathways.

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Significance of orchids in neuroprotective and cognitive health

Increasing experimental and clinical evidence suggests the neuroprotective and cognitive-enhancing effects of medicinal orchids, especially *Dendrobium* species in the management of neurodegenerative diseases and memory loss. *Dendrobium nobile* alkaloids have shown significant neuroprotective effects in the models of Alzheimer disease, including the reduction of neuronal damage, the delay of cognitive decline and the alteration of aging-related pathways (32). Furthermore, flavonoids of *D. officinale* have been reported to improve cognitive performance by altering the gut-brain axis and decreasing neuroinflammation, which may be a new mechanism of action (45).

Quantitatively, phytochemical investigations reveal that more than 60 bioactive compounds have been isolated from species such as *D. officinale*, many of which contribute to neurorestorative and anti-aging effects, further supporting their role in maintaining cognitive health (46).

Significance of orchids in gastrointestinal health

Orchids, particularly *Dendrobium* species, have demonstrated significant potential in enhancing gastrointestinal health by various pharmacological effects such as mucosal protection, anti-inflammatory effect and modulation of the gut microbiota. Research shows that *Dendrobium* bioactive compounds, including polysaccharides, flavonoids and alkaloids are essential in the prevention and treatment of digestive tract-related diseases by alleviating oxidative stress, controlling the inflammatory process and enhancing gut functions (47).

Dendrobium officinale polysaccharides have been shown to heal gastric mucosal injury through experimental research by regulating signalling pathways, including mitogen-activated protein kinase (MAPK) and promoting epithelial regeneration and decreasing inflammation in gastric tissues (48). Moreover, recent discoveries contribute to the idea that *Dendrobium* compounds have a positive effect on gut microbiota by increasing the numbers of beneficial bacteria, including *Lactobacillus* and *Bifidobacterium* and by stimulating the production of short-chain fatty acids and boosting the overall digestive system (49) (Fig. 3).

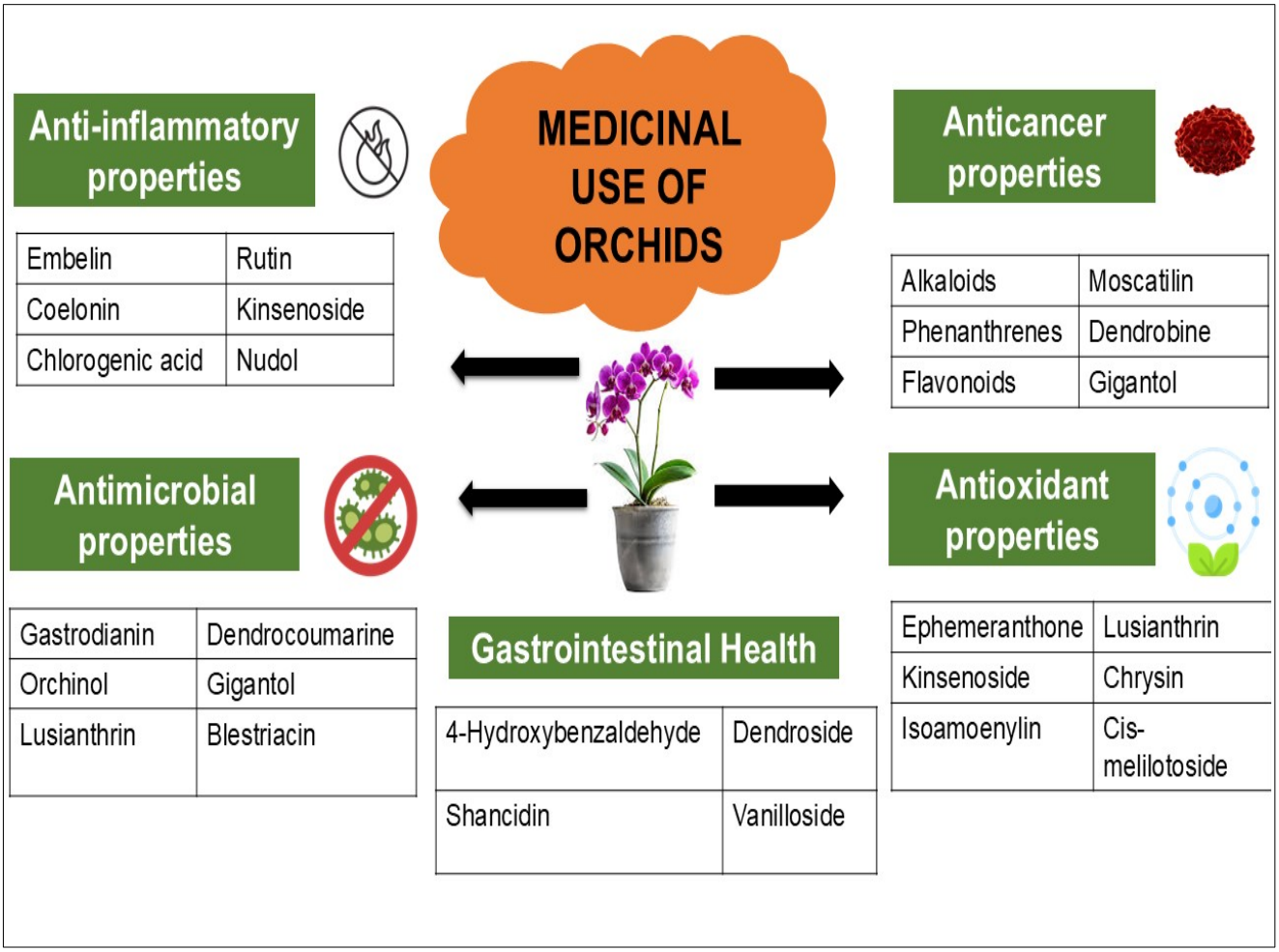


Fig. 3. Summary of the medicinal properties of orchids.

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Application of orchids in food

Nutritional and functional components of orchid

Edible terrestrial orchid tubers and flowers are increasingly being identified as useful sources of nutritional and functional components to human health. The dried tuber of orchid species has been reported to contains a high level of carbohydrates (65.80 %), moderate protein composition and important mineral contents including iron (Fe), potassium (K), calcium (Ca) and phosphorus (P), which demonstrates their functioning as sources of energy-dense foods. They contain total phenolic compounds (as much as 500 mg GAE/100 g) which promote their antioxidant action (50). Moreover, these orchids contain phytochemicals such as phenols, flavonoids, alkaloids and terpenoids that are related to antioxidant and medicinal activities (51). The presence of phenolic compounds with strong antioxidant activity has been confirmed by studies on orchid species like *Phalaenopsis*, as potential natural health-promoting ingredients in food systems (52). The table depicts the nutritional benefits of orchids (Table 4).

Flavouring agents from orchids

Orchid-derived flavouring agents are primarily associated with the genus *Vanilla* and *Vanilla planifolia* Jacks. ex Andrews. in particular, which is the sole orchid widely used in the production of food flavours. The typical taste of vanilla is primarily brought about by vanillin, which is a phenolic aldehyde and forms the primary aromatic constituent of the over 200–250 volatile constituents produced in the process of curing the vanilla pods (53). Vanilla is regarded as one of the most popular natural flavouring agents in the world and it is widely used in ice creams, confections, dairy products, beverages and pharmaceuticals because of its pleasant smell and sensory properties (54). Orchidaceae constitute one of the most important sources of natural flavouring agents of botanical interest, *V. planifolia* Andrews being the most important trade species. Natural vanilla is a complicated blend of flavours derived through the extraction of the cured pods of *V. planifolia* and *Vanilla tahitensis* J.W.Moore., the flavour and fragrance profile includes over 200 compounds with vanillin (4-hydroxy-3-methoxybenzaldehyde) the most important substance appearing at a level of 1–2 % w/w in cured vanilla pods (55).

Beverages made with orchids

Orchid-based beverages are one of the oldest and most culturally important uses of plants of the family Orchidaceae, the most important product in the category being salep, a hot drink made of the dried and powdered tubers of terrestrial orchid species. Salep powder of the tubers of the Orchidaceae has received significant research attention due to the distinctive functional properties and nutritional qualities; glucomannan is a useful thickener and stabiliser in the classic beverage and in hard-serve ice cream and purification of glucomannan by eliminating starch, protein and ash strongly contributes to the viscoelastic behaviour (56). The flowers of *D. officinale* have more recently received interest as a potential functional tea beverage ingredient due to their characteristic aroma and presence of bioactive compounds particularly flavonoids, phenolic compounds, amino acids and polysaccharides, which in combination imparts anti-aging, anti-stress and health-promoting properties when ingested (57). A *D. officinale* National Herbal Drink (NHD) approved by the State Administration for Market Regulation of China has been shown to increase immunity and improve liver and intestinal function in chronic drinkers with impaired immune systems, namely by increasing the intestinal immune barrier, correcting gut microbiota imbalances and altering gut-liver axis communication (58).

Table 4. Comparative nutritional profile of edible orchid species, presenting the geographical regions of use, proximate nutritional composition and associated functional properties

Orchid species	Region of use	Carbohydrate (%)	Protein (%)	Total phenolics (mg GAE/100 g)	Minerals	Functional properties
Satyrium trinerve	Malawi	77.10	4.10	460	K, Mg, Fe	High swelling index; potential thickener
Gastrodia elata	China, India	70.00	3.50	310	P, K, Ca	Neuroprotective; used in TCM
Habenaria spp.	Nepal, Bhutan	~72.00	~3.00	~250	Ca, P, Fe	Used in salep
Eulophia nuda	India	68.40	3.80	275	Ca, Fe, Mn	Anti-inflammatory
Disa zombica	Malawi	65.24	2.19	228	Fe, Ca, K	High water absorption capacity (8.12 g/g)
Satyrium buchananii	Malawi& Tanzania	80.22 used in tribal medicine	4.65	500	Fe, Mg, Zn	Gel-forming ability; used in chikande sausage

K: potassium; Mg: magnesium; Fe: iron; P: potassium; Ca: calcium; Zn: zinc.

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Orchid flower products

Vanilla extracted as a flavouring agent made out of *V. planifolia*, the capsules of which are a globally treasured culinary ingredient. It is the most well-known orchid-derived food item and *Leptotes bicolor* Lindl. of Brazil is a vanilla substitute utilised in flavouring ice cream and beverages (59). In Thailand, *Dendrobium* flowers are batter-dipped and deep-fried as crunchy snacks and orchid petals are used to garnish desserts and cakes by European confectioners and the pseudostems of soft-cane *Dendrobium*s are made into sauces in Japan and Singapore (60). Fresh orchid flowers are added to salads in Hawaii or candied and coated in sugar, orchid ice cream is made in Turkey, called dondurma and is uniquely chewy and resistant to melting, made with the same powdered tuber as the traditional beverage salep with sugar, milk and mastic (61). A phytochemical study of *D. officinale* and *Dendrobium devonianum* Paxton. flowers revealed 474 metabolites such as flavonoids, amino acids and fatty acids with antioxidative properties, proving their appropriateness in being used as functional food and medicine (62). The following table summarises the use of orchids in food and edible products (Table 5).

Toxicological and food safety considerations of orchids as food

Detailed chemical profiling indicates that orchids synthesise active alkaloids whose specific molecular structures and concentrations require systematic evaluation to eliminate potential toxicity (66). Ethnobotanical evidence demonstrates that traditional culinary preparation methods, such as blanching, boiling, or hot-water steeping, significantly reduce the levels of these thermolabile anti-nutrients in orchid tissues (67). Furthermore, edible orchid blooms are frequently served raw or minimally processed as fresh garnishes; food safety authorities emphasise compliance with Good Agricultural Practices (GAP) to prevent contamination by pathogenic microorganisms such as *Salmonella* spp. and *Escherichia coli* (68).

Application of orchids in cosmetics

The anti-aging benefit of using orchid

The anti-aging benefits of orchids have attracted significant attention in cosmetic research. This interest is due to bioactive phytochemicals that have strong antioxidant, collagen-stimulating and skin-protective qualities. Phytochemical study has identified diverse compounds, including phenolics, bibenzyls, polysaccharides, flavonoids, lignans and phenanthrenes, across multiple *Dendrobium* species. These compounds contribute to skin rejuvenation and anti-aging effects (69). Experimental studies confirm that extracts from *D. officinale* flowers can scavenge free radicals. They also have a strong impact on skin ageing markers in both *in vitro* and *in vivo* models. This supports their ability to delay oxidative damage and maintain skin integrity (70). Besides *Dendrobium*, other orchid genera such as *Vanda* and *Phalaenopsis* also show moisturising and skin-repair effects that help improve skin texture and slow down ageing signs in cosmetic products (71). Reviews on medicinal orchids highlight bioactive flavonoids, phenanthrenes and stilbenoid compounds. These compounds help regulate signalling pathways, such as NF-κB and MAPK, to reduce chronic inflammation related to ageing (3). However, much of the evidence for orchid-derived anti-aging activity remains preclinical and further well-designed human clinical studies are required to establish their efficacy in cosmetic applications.

Table 5. Food and edible products derived from orchid, highlighting the edible plant parts used and their commercial food applications

Sl. No.	Orchid species	Plant parts used	Edible products prepared	Citation
1	*Satyrium buchananii* Schltr.	Tubers	Flour preparation, porridge, meatless sausage (Chikanda) in Malawi and Zambia	(50)
2	*Orchis mascula* (L.) L.	Underground tubers	Salep (hot beverage), salep ice cream (*dondurma*), bread and confectionery	(61)
3	*Dendrobium officinale* Kimura & Migo	Flowers and stems	Functional health beverages, herbal tea and health food supplement products	(62)
4	*Bletilla striata* (Thunb.) Rchb.f.	Tubers (rhizomes)	Herbal tonic preparations and medicinal food in traditional Chinese medicine (TCM)	(13)
5	*Vanilla planifolia* Andrews	Fruit pods (seed capsules)	Vanilla extract, flavouring for ice cream, baked goods, beverages and confectionery	(63)
6	*Leptotes bicolor* Lindl.	Seed capsules (fruits)	Vanilla substitute; used to flavour ice cream and beverages in Brazil	(63)
7	*Dendrobium nobile* Lindl.	Flowers and dried stems (canes)	Herbal tea, deep-fried flower snacks, stir-fry and garnishes on cakes and desserts	(64)
8	*Dendrobium chrysotoxum* Lindl.	Flowers	Dried flower tea consumed for pleasure and general health	(64)
9	*Dactylorhiza hatagirea* (D.Don) Soó	Young leaves, shoots and tubers	Vegetable dish (boiled greens) and salep-like preparations	(65)
10	*Habenaria intermedia* D.Don	Roots and leaves	Boiled roots eaten as food and leaves cooked as vegetables in Nepal	(65)

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Utilisation of orchids for skin hydration and moisture retention

Recent studies have demonstrated that several orchid genera, particularly *Dendrobium*, *Vanda* and *Phalaenopsis*, possess significant moisturising efficacy by enhancing skin barrier function and increasing water retention capacity. Among these, *D. officinale* has received considerable attention because its polysaccharides exhibit strong hygroscopic activity and stimulate endogenous moisturising pathways associated with aquaporin proteins and hyaluronic acid metabolism (72). *In vitro*, polysaccharide extract of *Dendrobium candidum* Wall. ex-Lindl. (PDC) substantially enhanced the expression of filaggrin (FLG), caspase-14 and bleomycin hydrolase. These are the major factors involved in skin hydration and induced mRNA expression of occludin and claudin-1 for epidermal barrier function. Furthermore, topical PDC treatment noticeably improved skin hydration and elasticity of the skin over a period of 2 weeks (73). A randomized, placebo-controlled, double-blind human study conducted by measuring the skin hydration and transepidermal water loss (TEWL) of volunteers using the C+K multiprobe skin testing system after 56 consecutive days of treatment with fermented *D. officinale* extract, found that parameters such as skin hydration, TEWL, skin elasticity and skin erythema significantly improved (74).

Thus, among the cosmetic applications discussed, hydration has comparatively stronger human evidence; additional clinical studies are needed to confirm long-term efficacy and reproducibility.

Utilization of orchids for skin brightening

Orchid genera such as *Dendrobium*, *Vanda*, *Phalaenopsis* and *Anoectochilus* contain phenanthrenes, flavonoids, bibenzyl derivatives and polysaccharides capable of reducing melanin synthesis and improving skin pigmentation through inhibition of tyrosinase activity and modulation of melanogenesis-related pathways (75). At the phytochemical level, propanolic extracts of the *Dendrobium* Pearl Vera hybrid were identified to possess 25 bioactive constituents, including phenolics, flavonoids, alkaloids, salicylic acid and nicotinamide. These constituents inhibited human tyrosinase in a concentration-dependent manner and considerably diminished melanin production in human melanoma cells when compared to standard arbutin (76). Quantitative studies further indicate that orchid-derived antioxidants can reduce intracellular oxidative stress by more than 40 % in keratinocyte cell models, thereby contributing to a brighter and healthier skin appearance (77). However, these findings are primarily based on cellular and biochemical assays and human trials evaluating orchid-derived ingredients for pigmentation reduction remain limited.

Utilisation of orchids in UV protection formulations

Orchid extracts are useful for UV protection because they have high levels of flavonoids and polyphenols. These compounds can absorb UV radiation in the 200–400 nm range. They also provide antioxidant and anti-inflammatory benefits, making them safer and more effective than many synthetic UV filters. Bibenzyl derivatives from *D. officinale* are crucial for shielding skin cells from UVB damage. They activate the SIRT3 protein, which boosts antioxidant defences by reducing Mn-SOD acetylation and scavenging ROS (78). Studies indicate that extracts of *D. officinale* effectively guard against skin photoaging by reducing ROS, preventing apoptosis and improving autophagy in models of UV-induced skin damage. This leads to better skin elasticity and hydration (79). Further supporting the UV-protective qualities of orchid polysaccharides, DOPs from stems demonstrate a dual-action defence in UVB-irradiated HaCaT human keratinocytes. They increase antioxidant enzyme activities while also lowering MAPK signalling pathway activation. This suppression results in reduced levels of p53 and matrix metalloproteinases MMP-1 and MMP-9, which play key roles in UV-induced collagen breakdown and photoaging (80).

Utilisation of orchids in hair care products

Hair care products with orchid extracts have drawn interest because of their bioactive compounds, including flavonoids, phenolics and polysaccharides. These compounds help with hair growth, conditioning and scalp health. Research on substances from orchids, especially *Dendrobium* spp., shows that orchid callus extracts can boost hair follicle activity and promote the proliferation of hair follicle stem cells. This makes them promising ingredients in hair oils and serums that aim to reduce hair loss and encourage regrowth (81).

The study found that the wingless-related integration site (WNT) signalling mechanism offers a strong scientific and practical basis for using DOPs in treating hair loss. This supports adding them to hair care products like scalp oils, tonic serums and leave-in conditioners that focus on androgenetic alopecia (82).

Additional evidence suggests that DOP may help promote hair growth by supporting the regeneration of blood vessels around hair follicles and enhancing microcirculation. This happens through the upregulation of vascular endothelial growth factor (VEGF) mRNA expression, creating a nutrient-rich environment crucial for follicular activity (83) (Fig. 4).

Orchids in the fragrance and perfumery industry

Phytochemical investigation of *Dendrobium* stems identified 17 aroma-active volatile compounds through solid-phase microextraction–gas chromatography–mass spectrometry (SPME-GC-MS) analysis. These included methional and 1-octen-3-one, which are key contributors to the fragrance quality of orchids and consumer preference (84).

Orchids are highly valued in the perfume and fragrance industry for their unique and complex scents. These scents can be sweet and floral or spicy and woody. Natural fragrance compounds from orchids, especially from the *Vanilla* and *Dendrobium* genera, contain many volatile components like vanillin, phenolics

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and terpenoids. These compounds play a significant role in making high-quality perfumes and scented products (85). The table summarises the cosmeceutical applications of orchids (Table 6).

Future prospects

The future potential of Orchidaceae in the pharmaceutical, food and cosmetic industries is considered highly significant, although several challenges continue to limit their full utilisation, including inadequate clinical evidence, sustainability issues and obstacles in commercialisation (18).

Metabolomics offers a powerful strategy for expanding the discovery of bioactive compounds in orchids by integrating comprehensive chemical profiling with biological activity assessment. ultra-high-performance liquid chromatography-tandem mass spectrometry (UHPLC-MS/MS)-based metabolomic analysis of *D. officinale* identified diverse secondary metabolites and differentiated metabolite profiles among samples from different geographical origins, with several flavonoids, alkaloids and phenolic acids associated with variation in antioxidant activity (95). Emerging biotechnological tools, particularly CRISPR/Cas-based genome editing and epigenetic modifications, are expected to accelerate the development of improved orchid varieties possessing enhanced ornamental and medicinal traits while also supporting conservation efforts by reducing dependence on wild germplasm (96).

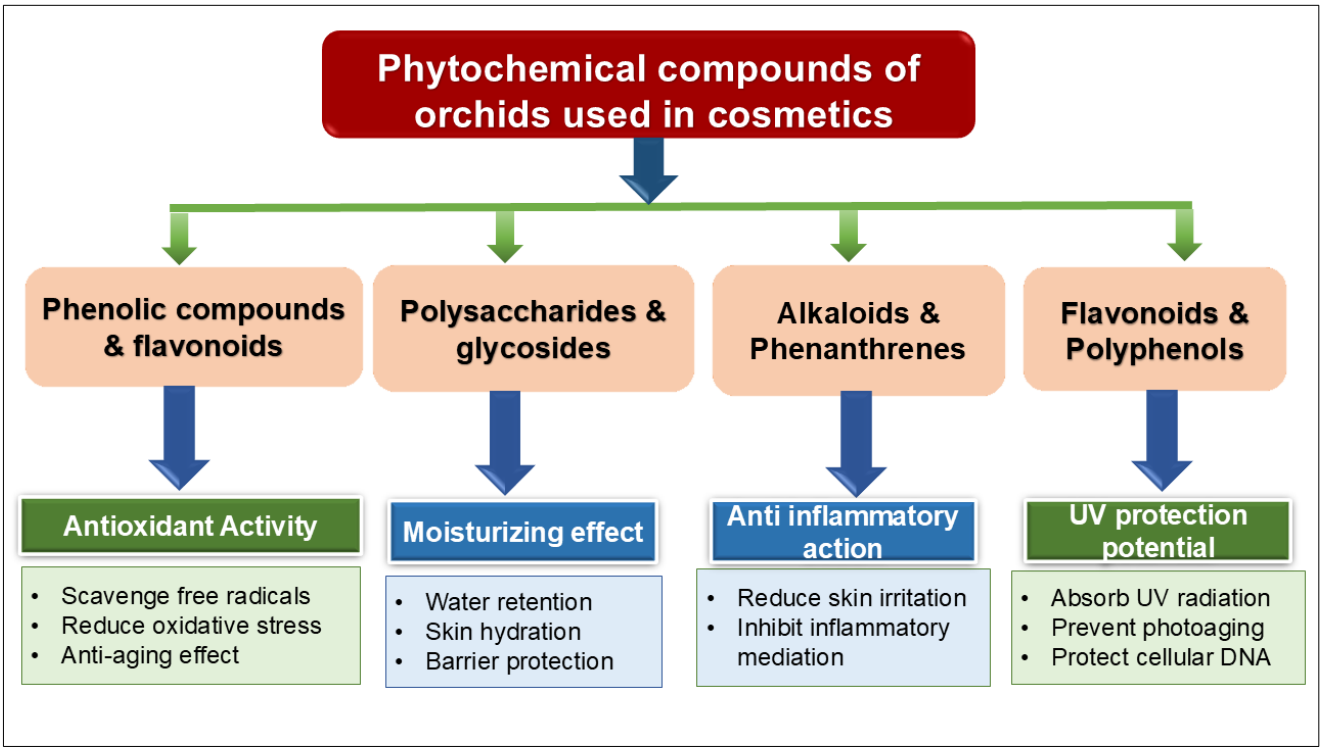


Fig. 4. A schematic representation of phytochemical compounds present in orchids and their application in cosmetics.

Table 6. Compilation of orchid species used in cosmetics, illustrating the relationship between the plant parts utilised, their bioactive properties and cosmeceutical applications

Sl. No.	Orchid species	Plant parts used	Cosmetic uses	Reference
1	*Dendrobium kentrophyllum* Hook.f.	Whole plant extract	Anti-ageing microemulsions; MMP-2 inhibitory activity (94.96 %); anti-wrinkle topical formulations	(9)
2	*Dendrobium sulcatum Lindl.*	Stems, leaves, flowers	Ethanolic extracts show antioxidation, anti-lipid peroxidation, antiglycation and tyrosinase inhibition; leaf extract shows highest flavonoid content and DPPH radical scavenging activity; used in anti-aging serums and creams.	(86)
3	*Phalaenopsis aphrodite Rchb.f.*	Flowers, stems (exosome-like vesicles)	Plant-derived extracellular vesicles (~98 nm) penetrate keratinocytes within 24 h; reduce UV-induced ROS; deliver anti-aging and brightening benefits without irritation; used in advanced skin-conditioning cosmetic serums.	(87)

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	Bletilla striata (Thunb.) Rchb.f.	Tubers	*Bletilla striata* polysaccharide provides moisture retention; tyrosinase inhibit 52.9 % for skin whitening; promotes fibroblast proliferation for skin regeneration; hemostatic and anti-acne properties; used in facial masks and wound-care formulations.	(88)
5	*Gastrodia elata* Blume	Tubers	*Gastrodia elata* polysaccharide (GEP) reduces oxidative stress in aging skin; inhibits bacterial growth; promotes angiogenesis and collagen deposition; used in anti-aging hydrogels and wound-repair cosmetics.	(89)
6	*Vanilla planifolia* Andrews	Fruit	Vanillin and phenolic acids provide antioxidant and anti-inflammatory activity; soothes irritated skin; natural fragrance and skin-conditioning agent; used in body lotions, perfumes and lip balms.	(90)
7	*Cymbidium* spp. (hybrid)	Pseudobulbs, roots, flowers	Ethyl acetate extracts inhibit tyrosinase, elastase and collagenase; flavonoids contribute antioxidant activity; flower extract used in perfumes, skin creams and anti-aging cosmetics; naturally-derived light emollient enhancing product spreadability.	(91)
8	*Dendrobium nobile* Lindl.	Stem (Shihu) flower	Anti-ageing creams; moisturising serums; skin brightening; antioxidant formulations	(92)
9	*Dendrobium loddigesii* Rolfe	Stem	Skin whitening; anti-ageing collagen stimulation; antioxidant formulations	(93)
10	Cattleya walkeriana	Flower extract	Antifungal, preservative in cosmetic formulations and skin protection.	(94)

Artificial intelligence and machine-learning approaches represent promising tools for accelerating phytochemical screening, compound prioritisation and optimisation of extraction processes in orchids. Recent research on *Dendrobium flexicaule* J.J.Sm. combined untargeted metabolomics, response-surface methodology and machine-learning-based predictive modelling to optimise flavonoid extraction and investigate relationships between metabolites and antioxidant activity, demonstrating the potential of computational approaches to improve the discovery and utilisation of orchid bioactives (97). Sustainable cultivation practices are also becoming increasingly important for orchid conservation and biodiversity protection. Techniques such as *in vitro* propagation, controlled-environment cultivation and symbiotic seed germination involving mycorrhizal fungi are now widely recognised as effective strategies in orchid conservation programs (98). Standardisation is essential for ensuring consistent composition, efficacy, safety and reproducibility of orchid-derived extracts intended for pharmaceutical, food and cosmetic applications. Research on *D. officinale* has demonstrated that geographical origin, cultivation conditions, harvesting and processing can substantially influence polysaccharide and secondary-metabolite profiles, indicating that a single quality marker may not adequately represent the overall quality of the plant material (99). Collectively, these research priorities can help bridge the gap between laboratory discoveries, clinically validated and sustainably produced orchid-derived products.

2. Conclusion

Orchids are emerging as multipurpose plants with applications extending far beyond their traditional ornamental value, owing to their rich biochemical and phytochemical profiles, which support applications in medicine, food and cosmetics. They contain bioactive compounds such as alkaloids, flavonoids, terpenoids, bibenzyl derivatives, phenanthrenes, phenolics and polyphenols, which have demonstrated antimicrobial, antioxidant, anti-inflammatory, antitumour and immunomodulatory activities, highlighting their potential for pharmaceutical and therapeutic applications. Selected orchid species also contain valuable nutritional constituents, supporting their potential as nutraceutical ingredients and functional foods. In addition, orchid-derived bioactive extracts and aromatic compounds have gained attention in cosmeceuticals for potential applications in skin hydration, anti-aging, photoprotection and fragrance development.

Despite promising potential, several limitations currently constrain the development and commercialisation of orchid-derived products. Pharmacological evidence remains largely based on *in vitro* and animal studies, with limited clinical validation of efficacy, safety, dosage and bioavailability. Phytochemical composition also varies with species, plant part, developmental stage, environmental conditions and extraction procedures, affecting reproducibility. The lack of standardised extraction and quality-control protocols further limits product consistency. Moreover, unsustainable collection of wild orchids can threaten vulnerable species, emphasising the need for sustainable cultivation and conservation.

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Regulatory requirements for establishing safety, efficacy, quality and compositional consistency also remain important barriers. Future research should prioritise clinical validation, standardised extraction, metabolomics-guided characterisation and sustainable production to facilitate the development of scientifically validated and commercially viable orchid-based products.

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Authors' contributions

HDR contributed to the literature collection and preparation of the initial manuscript draft. JV contributed to its conceptualisation and drafted the manuscript. JV and GM compiled and organised the references. SBK and SM critically revised the manuscript for intellectual content and corrected the final version. HM contributed for literature search and editing. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest

Authors do not have any conflict of interests to declare.

Ethical issues

None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the author used Grammarly to correct grammatical errors and improve the overall English language consistency of the manuscript. The author reviewed and approved all changes made with the assistance of the tool.

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