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Exploring the nutritional and medicinal properties of *Brassica oleracea var. Gongylodes* (Kohlrabi): A comprehensive review

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Abstract
Brassica oleracea var. gongylodes (kohlrabi), a lesser-explored member of the *Brassicaceae* family, is gaining recognition for its impressive nutritional, medicinal, and experimental attributes. Rich in bioactive compounds such as glucosinolates (glucoiberverin, glucoiberin, and glucoraphanin), anthocyanins, carotenoids, phenolics, and phytoalexins, kohlrabi demonstrates diverse therapeutic properties, including antioxidant, anti-inflammatory, anti-diabetic, and anti-carcinogenic effects. The interesting morphological characteristic of the plant particularly the de novo shoot organogenesis (DNSO) framework, are a great candidate for organic considers within the field of plant improvement and gives thoughts around sugar signals, tissues and hormones. Despite its sub-relief, Kohlrabi has significant potential for human health, especially functional foods and nutritional resources. However, challenges such as limited public awareness, insufficient phytochemical profiling, and a lack of comprehensive genomic and pharmacological data hinder its broader application. This wholes up our current understanding of the naturally dynamic composition of Kohlrabi, combining helpful benefits with test applications, supplement and modeling framework in biological studies.

Keyword: DNSO, Kohlrabi, bio-fortification, genomic data, sugar signaling, phyto-hormonal interactions, plant science innovation

1. Introduction
World plant biodiversity is the biggest source of herbal medicine and still approximately 60-80% world population depend on plant-based medication which being utilized since ancient ages as the traditional health care system. According to the World Health Organization (WHO), therapeutic plants would be the leading source to obtain an assortment of drugs. However, such plants ought to be investigated to superior understand their properties, safety and effectiveness. Medicinal plants are the most abundant organic resources of drugs in traditional frameworks of pharmaceuticals, nutrients, dietary supplements, folk medicines, intermediate pharmaceutical products, and manufacturing medicinal chemical units. The recent achievements of functional nutrition and vegetative chemicals, which occur in other parts, such as leaves, seeds, fruits and food systems, have a variety of positive effects on various aspects of human health and nutrient life [1-2]. The mustard family, also known as *Brassicaceae* or *Cruciferous*, is a distinct group of blossoming plants of the order *Brassica spp*. The *Brassica* family can be a rich source of essential and additional metabolites [3]. The *Brassicaceae* family contains up to 338 genera and 3709 species of angiosperm dicotyledonous plants characterized by a Greek cross structure of the four petals that shape the bloom. It is distributed all over the world across all continents without Antarctica [4-7]. The advantageous impacts of vegetables and their by-products have been fundamentally considered in later a long time as a source of profitable bioactive connections (BACs) through the treatment and anticipation of human-diseases such as diabetes, cancer, inflammation, lipid oxidation, cardiovascular illness (CVD) systems and urine infections and related clutters [8-11].
Beyond their antioxidant and anticancer effects, Brassica species demonstrate promising anti-diabetic and anti-inflammatory activities. For example, red cabbage (*B. oleracea Var. capitata*) has a significant effect on free radicals and anti-inflammatory effects, while green and red Kohlrabi varieties have strong inhibitory activity against protein tyrosine phosphate 1B (PTP1B), which is associated with type 2 diabetes [12-16].

The purpose of this overview is to provide a detailed analysis of the plant chemical composition of the *Brassicaceae var. Gongylodes*, highlighting the factors that influence health-promoting properties and biological activity profiles. Through the integration of current review, we seek to highlight the potential of *brassica* vegetables as functional foods and natural therapeutics.

2. Botanical Classification & Taxonomy [17-21].

Brassica

- **Kingdom:** Plantae.
- **Subkingdom:** Tracheobionta (Vascular plants).
- **Super-division:** Spermatophyta (Seed plants).
- **Division:** Magnoliophyta (Flowering plants).
- **Class:** Magnoliopsida (Dicotyledons).
- **Order:** Brassicales.
- **Family:** *Cruciferous* (also known as *Brassicaceae* or mustard family).
- **Genus:** *Brassica.*
- **Species:** *Brassica oleracea* L.
- **Subspecies:** *Brassica oleracea Var.Gongylodes* (L.)
- **Common Name:** Kohlrabi, stem-turnip, Knol-Khol.

3. Biological Properties

3.1 Anti-mutagenic (Desmutagenic) Properties: Thermo-labile desmutagenic factors (a 53 kDa protein with a heme like chromophore) neutralize various mutagens [19, 20, 22].

Active against

- Tryptophan pyro-lysate.
- Ethidium bromide.
- Autoxidized linolenic acid.
- Other pyro-lysates.

Mechanism: Often desmutagenic (inactivates mutagens before DNA interaction). After warm treatment, leftover movement is an extra uncontrolled starting action (i.e. non-protein antimutagenic activity) [11, 23].

3.2 Chemical Reduction of Mutagens: The presence of ascorbic acid and phenol compounds in cabbage/cauliflower reduces nitrosation i.e.NO-group/products (e.g., converting mutant genes into 1.2-dinitro-2-methyl pyrrole are converted into non-mutagenic forms) [8, 23, 24].

3.3 Specific Anti-mutagenic Compounds: Compounds such as β-sitosterol, pheophytin-a, nonacosane, and nonacosanone, isolated from *Brassica oleracea*, demonstrate mutagen-specific antimutagenicity. The commercial chlorophyll of the predecessor Pheophytin-A also shows a strong anti-mutagenic effect assuming several action mechanisms [8, 19-21].

3.4 Stimulation of Detoxification Mechanisms [2, 5, 8, 24, 25]

Phase-1 and Phase-2 enzyme induction, particularly:

- Cytochrome P450 chemicals (e.g., aryl hydrocarbon hydroxylase).
- Glutathione-S-transferase (GST): Vital for phase-2 detoxification.

Notable Enzyme-Inducing Compounds:

- Indole-3-carbinol.
- 3, 3'-diindolylmethaneIndole-3-acetonitrile.
- Glucosinolates: Sinigrin, progoitrin and their subsidaries (e.g., allyl isothiocyanate, goitrin).

These induce liver and gut detox enzymes, aiding in xenobiotic clearance

3.5 Anti-inflammatory and hormone-modulating properties: Inhibition of low-level inflammation & Reduction of estrogenic stimulation, both recognized as cancer-promoting influences [8-11].

3.6 Enzyme Specific Actions: Glutathione-S-transferase induction by Brussels sprouts results in: Up to 87% reduction in aflatoxin-DNA binding (important in liver cancer prevention) [10].

4. Traditional value

Brassica species have long been highly regarded in traditional healthcare systems of various cultures due to their health promotion properties. Distinctive plant parts seeds, leaves, roots, and flowers have been customarily utilized for treating sickness such as aggravation, contamination, stomach related dissaranges, and respiratory issues. In folk medicine, *Brassica* arrangements were utilized to diminish indication of colds, joint torment, and wounds, frequently leveraging their normal antimicrobial and anti-inflammatory impacts. The seeds are gaining modern scientific interest due to their rich profile of bioactive compounds that show promise in the prevention and management of chronic diseases such as obesity, diabetes, cancer, and viral infections like COVID-19 [8, 25, 26].

5. Historical Significance

The family *Brassicaceae (cruciferous)* also includes the genus *Brassica* is one of the oldest and most widespread family of plant species in human agriculture. With around 338 genera and over 3,700 species, crucifers have been a staple food source throughout human-history. The genus *Brassica* stands out as the most economically and culturally important genus within the family. Historically, it has provided vegetables, oilseed crops, forage, and green manure, contributing to food security, livestock nutrition, and soil-fertility. The six main species of the *Brassica* genus—three diploids (*B. nigra*, *B. oleracea*, *B. Rapa*) and three amphidiploids (*B. juncea*, *B. carinata*, *B. napus*)—have been selectively bred over centuries, giving rise to a wide range of cultivars adapted for both culinary and medicinal uses [5, 23, 24, 27].

6. Nutritional, health benefits & genetic diversity

Brassica plants are developed as agricultural and outdoor plants around the world and are utilized for an assortment of purposes, including vegetables, oils, nourishments, green slurries/manure, and flavors. The foremost imperative taxa are *B. oleracea* (e.g. Kohl, cauliflower, Broccoli), *B. Rapa* (e.g. Beet, Napa-Kohl), *B. Incorporates Napus* (Swede), and *B. Juncea* (Indian mustard).These crops are consumed for various plant parts such as roots (e.g., turnip, swede), stems (e.g., kohlrabi), leaves (e.g., kale, cabbage), and inflorescences (e.g., broccoli, cauliflower).

Kohlrabi has higher add up to and fundamental free amino corrosive substance than radish, proposing superior dietary esteem. Its glucosinolate profile, especially high levels of glucoiberverin, glucoiberin, and glucoraphanin, highlights its potential health benefits, particularly its anticarcinogenic potential via sulforaphane [5, 12, 13, 19, 22, 28].

The preservation and evaluation of genetic resources in *Brassica* species are vital for crop improvement, breeding programs, and long-term food security. Important plant materials such as landraces, advanced varieties, inbreeding lines, double haploid lines, and hybrids must be preserved and

characterized to ensure genetic diversity. Seed collections from the *Brassicaceae* family represent a rich molecular resource, with studies utilizing amplified fragment length polymorphisms (AFLPs) to assess genetic variability across accessions of *B. oleracea* and its varieties [29-31].

7. Plant Physiology & Model System

In addition to Arabidopsis, KOHLRABI can function as a secondary model system from the regenerative mechanism and similarity. One-step de novo shoots organogenesis (DNSO) and carbohydrate cumulative accumulation in stem tubers are valuable in testing for signaling and sugar development [5, 32, 33].

8. Agronomic & Stress Response

The Kohlrabi is a multi-functional crop worth deeper exploration as it has high nutritional & experimental values & tolerance to abiotic stress & it is suitability for a variety of growth. It also collects high level of anthocyanins in stem of purple varieties [19, 34-36].

9. Phytochemical Compounds/Constituents

Brassicaceae vegetables are important plants around the world that arise due to their unique flavors and occur due to commonly recognized functional properties that are directly related to plant chemical composition. ITC (Isothiocyanates) is the most characteristic compound and is considered to participate in a sharp taste. In expansion to ITC, this vegetable is wealthy in carotenoids, phenols, minerals and vitamins [6, 22, 26, 28]. Phytochemical investigation of Kohlrabi extracts using HPLC and GC-TOFMS identified the presence of organic acids, amino acids, sugars and amines, anthocyanins, glucosinolates, phenylpropanoids, carotenoids, purple and pale green kohlrabi cultivars, except for the absence of anthocyanins in pale green kohlrabi [12, 15, 19].

Phytochemical studies of *B. oleracea var. gongylodes*, involving isolation of compounds are scarce stem tuber of kohlrabi provided six distinguishable phytoalexins in the chloroform extract of treated tuber, namely, methoxybrassitin, methoxybrassinin, cyclobrassinin, cyclobrassinon, spirobrassinin and 1-methoxyspirobrassi nin[20,21].

9.1 Phenolic Compound

It is believed that phenol compounds contribute to health consumption related to food consumption in *Brassicaceae* species, such as antioxidants, anti-carcinogenetic and activation of detoxifying enzymes. In common, other categories of phenol compounds found in Brassicaceae family are the hydroxycinnamic acid gather characterized by flavonoids and structure of C6-C3. Furthermore, anthocyanins were associated to red or purple radish, purple cauliflower, and red cabbage ruddy or purple due to pigmentation [5, 8, 9, 24, 37].

9.2 Organo-sulfur compounds

The organic sulfur compounds accumulated by Brassicaceae species have been discovered, the most significant derivative metabolite i.e. is glycoside glucosinolate (GSL) sulfur. In the plant kingdom, over 120 different GSLs were described, but in the Brassicaceae, it reaches around 96, some of which are unique to a particular gender or species. When GSL is hydrolyzed by myrosinase (thioglucoside, glucohydrolase, EC 3.2.1.147), induction of GSL after abiotic or biological loading was often explained to increase the phytochemical mirror and upon tissue disruption, numerous breakdown products are formed, including isothiocyanates (ITCs), thiocyanates, nitriles, ascorbigen, indoles, oxazolidine-2-thiones, and epithioalkanes depending upon different factors like pH, temperature, presence of myrosinase interacting protein, and availability of ferrous ion [5, 8, 23].

9.3 Carotenoids

A few carotenoids, carotene and cryptoxanthin are the forerunner of vitamin A. This compound has been carefully examined on the subject of characteristics that progress wellbeing and organic capacities as a pigment with a few sets [5, 24].

9.4 Other Terpenes Present in Brassicaceae

Common terpenes compounds found in Brassicaceae species are tocotrienols and tocopherols. Phytosterols are another imperative lower terpene class. It was detailed to be anti-inflammatory, antitumor, anti-fertilization, and immunomodulatory action. It was also reported that Phyto-sterol reduces total serum or plasma cholesterol and low-density lipoprotein cholesterol [5, 8, 38, 39].

9.5 Phytoalexins

The Brassicaceae include phytoalexins i.e., present indolic ring with C3 substitution with N & S atoms that confers a unique structure [5, 20].

9.6 Alkaloids

Tropane a class of alkaloids ordinarily found in family of 43 Brassicaceae species demonstrating that 18 of them had a assortment of structures of alkaloids compound. The presence of GSL and isothiocyanates is additionally seen in this family [5, 24].

10. Pharmacological Activities

Brassica sp. is a vegetable having a place to the family *Brassicaceae*, which is one of the foremost imperative families developed worldwide. Some types of this family are of pharmacological interest. A few considers have uncovered that they show anti-inflammatory, anti-mycotic, photo defensive, anti-hyperglycemic, anti-carcinogenic and antioxidant activities. Some authors report the antioxidant action of brassica extracts in connection to different radicals. Among the methods for testing the ability of some compounds to act as free radical scavengers is the 1,1-diphenyl-2-picryl hydrazyl (DPPH) assay [6, 9-11, 26, 39, 40].

11. Medicinal & Therapeutic Properties

Knolkhol plants have enormous nutritional and medical value with therapeutic capabilities such as asthma, cancer, high cholesterol, heart disease, digestive disorders, muscle and nerve function, colon cancer, skin problems, weight loss, and more. Cultivation of Knolkhol increased after glucosinolates were discovered in all vegetables in the Brassica family, including radish, cabbage, Chinese cabbage, kohlrabi and broccoli. This connection has strong anti-carcinogenic properties. They are also important sources for anticancer "nutraceuticals" compounds, fibers (including pectin and cellulose), calcium, zeaxanthin, glucosinolate and phenolic [5, 13, 18, 25, 26, 34].

12. Toxicological Profile & Safety

Combined and individual treatments of Kohlrabi plants with SE (IV/VI) and I (I/V) were safe for human consumption based on: [34, 40, 41]

- Low HQ values for both Se (selenium) and I (iodine).
- Nutrient levels well below toxic thresholds
- No adverse physiological or morphological effects
- Positive nutritional contributions (especially Se)
- Se medication expanded chlorophyll and carotenoid content, which are beneficial compounds.
- The higher processing treatment I show an oxidative stress (increased in anthocyanins) response but does not reduce certain physiological damage or plant growth.
- The ETS activity and photochemical efficiency of PS II were not adversely affected, but this does not show physiological toxicity at the cellular level.

These findings support the safe bio-fortification of kohlrabi with Se and I for potential health benefits without risk of toxicity.

13. Current Challenges & Future perspective

13.1 Challenges

Despite the growing interest in *Brassica oleracea* var. *gongylodes* as a nutraceutical and experimental model crop, several key challenges remain that limit its broader utilization in agriculture, medicine, and research:

13.1.1 Underutilization and lack of awareness: Kohlrabi remains moderately underappreciated compared to other Brassica crops like broccoli, cabbage, or cauliflower. Restricted open awareness and showcase request have limited its development and incorporation in dietary recommendations [17, 27].

13.1.2 Insufficient phytochemical profiling: Although preliminary studies have identified various bioactive connections in kohlrabi, there is still a shortage of comprehensive phytochemical databases, particularly regarding cultivation and metabolomic changes under different environmental or stress conditions [12, 19, 20, 32, 33].

13.1.3 Limited Genomic and Transcriptomic Resources: Unlike show plants such as Arabidopsis thaliana, kohlrabi needs broad genomic and transcriptomic information. This hinders functional genomics studies, breeding programs, and the development of high-yielding or bioactive-rich cultivars [31-33].

13.1.4 Variability in Bioactive Content: The concentration of glucosinolate, anthocyanins, and phenolic can vary significantly depending on genotype, environmental conditions, soil quality, and post-harvest handling. This variation complicates standardization of pharmaceutical or nutritional applications [12, 19, 34, 35].

13.1.5 Lack of Standardized pharmacological evaluation: Numerous of the health-promoting claims of kohlrabi are based on *in vitro* thinks about or related Brassica species. More robust and controlled in vivo and clinical research is needed to verify the effectiveness and safety of humans [11, 13].

13.2 Future Perspectives

13.2.1 Development of functional foods and supplements: Given its rich profile of antioxidants, glucosinolates, and essential amino acids, kohlrabi holds potential as a base for developing functional foods, dietary supplements, and phyto-pharmaceuticals tailored for chronic diseases such as diabetes, cancer, and cardiovascular disorders [8, 26, 34].

13.2.2 Bio-fortification and Breeding Programs: Future breeding programs can focus on improving the content of specific biological activities (e.g., sulforaphane predecessors and anthocyanins) through traditional and molecular reproduction. Biofortification by selenium, iodine, or other micronutrients can further improve your health benefits [34, 41].

13.2.3 Genomic and biotechnological interventions: Advancing genome sequencing and transcriptomic studies of kohlrabi will help uncover genes associated with stress tolerance, phytochemical biosynthesis, and morphogenesis. Metabolic pathways can be manipulated to improve nutritional value using CRISPR/CAS9 and RNAi technologies [6, 31-33].

13.2.4 Application in Plant Developmental Biology: Its interesting de novo shoot organogenesis (DNSO) framework makes kohlrabi a promising auxiliary model for examining shoot start, hormonal signaling, sugar digestion system, and tissue regeneration [32,33].

13.2.5 Integration into global health strategies: With advance approval of its restorative properties, kohlrabi can be advanced in worldwide wellbeing nourishment programs, particularly in locales enduring from micronutrient insufficiencies or persistent illnesses connected to poor count calories [8, 21, 26, 34].

14. Summary

Kohlrabi (*Brassica oleracea* var. *gongylodes*) as a harvest of nutrition and experimental models of the Brassica family is a lesser-explored member of the Brassicaceae family, is gaining recognition for its exceptional nutritional, medicinal, and experimental attributes. It is characterized by swollen regulars rich in essential amino acids, glucosinolates (particularly glucoiberverin, glucoiberin, and glucoraphanin), anthocyanins, and primary and secondary metabolites, including carotenoids,phenolic and phytoalexins. These compounds confer it with anti-inflammatory, antioxidant, anti-diabetic, and anti-carcinogenic properties, supporting its classification as a functional food. Moreover, kohlrabi serves as a secondary model system complementary to Arabidopsis, due to its unique one-step de novo shoots organogenesis (DNSO) mechanism and high regenerative capacity, making it ideal for studying morphogenesis, phytohormonal interactions, and sugar signaling. Despite its substructure, Kohlrabi promises both human wellbeing and essential inquire about in plant science, proposing the require for more in-depth phytochemical, pharmacological, and hereditary considers to maximize the potential of demonstrate frameworks and supplement crops.

15. Conclusion

Brassica oleracea var. Gongylodes (Kohlrabi) represents a promising but overpowering part of the Brassicaceae family, advertising significant potential as a collect of dietary supplement assets and exploratory model's crop. Rich in essential nutrients, glucosinolates, anthocyanins, phenols and other bioactive compounds, it has a wide range of therapeutic properties including antioxidant, anti-inflammatory, antidiabetic and anti-carcinogenic effects. Its unique morphological traits, particularly the swollen stem tuber and one-step de novo shoot organogenesis (DNSO), make it an ideal system for developmental and physiological plant studies. Despite its health and scientific value, kohlrabi

remains underutilized due to limited public awareness, insufficient phytochemical and genomic data, and a lack of standardized pharmacological evaluations. Addressing these challenges through advanced breeding, biofortification, and integrative research could unlock its full potential for human health, agriculture, and plant biology. In general, Kohlrabi may be an important candidate for future utilitarian nourishment, pharmaceutical advancement and plant science innovation.

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