

Phytochemical Composition and Antimicrobial Activity of *Raphanus sativus*, *Brassica rapa*, and *Allium cepa*: A Review Article

Mustafa J. Jalal, Raghda W Khalid, Hajir Dawood Sulaiman Joban

Department of Biology, College of Sciences, University of Kirkuk

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Annotation: It has been known that medicinal and dietary plants are a rich source of bioactive compounds possessing therapeutic potential. There are three vegetables that take a centre stage in the list of commonly consumed vegetables: *Raphanus sativus* (radish), *Brassica rapa* (turnip, Chinese cabbage, pak choi) and *Allium cepa* (onion), which are rich in phytochemicals and have been reported to be antimicrobial in nature. This review is a critical analysis of the phytochemical composition of the three species of plants and appraisal of available literatures on the antimicrobial activity of these plants against bacterial and fungal pathogens. There is a focus on the key types of secondary metabolites, antimicrobial action mechanisms, and the factors that affect bioactivity. This paper has identified the prospective of these vegetables as sources of natural antimicrobial agents by refining and synthesizing available research with in-text citations and identifying gaps in the future.

Keywords: *Raphanus*, *Brassica*, *Allium*, phytochemicals, natural products.

1. Introduction

The increasing prevalence of antimicrobial resistance has intensified the search for alternative and complementary therapeutic agents derived from natural sources. Plants synthesize a wide array of secondary metabolites that play defensive roles against pathogens and environmental stress, many of which exhibit antimicrobial activity *in vitro* and *in vivo* (Cowan, 1999; Newman & Cragg, 2020). Edible vegetables belonging to the families Brassicaceae and Amaryllidaceae are of particular interest, as they are widely consumed, generally recognized as safe, and rich in bioactive compounds.

Raphanus sativus L. and *Brassica rapa* L. are members of the Brassicaceae family and are characterized by the presence of glucosinolates and their hydrolysis products, which have been associated with antimicrobial, antioxidant, and anticancer effects (Fahey *et al.*, 2001; Cartea *et al.*, 2011). *Allium cepa* L., a member of the Amaryllidaceae family, is well known for its sulfur-containing compounds, flavonoids, and phenolic acids, which contribute to its strong antimicrobial and medicinal properties (Griffiths *et al.*, 2002; Lanzotti, 2006).

The purpose of the review is to provide an overview of the phytochemical composition of *R. sativus*, *B. rapa*, and *A. cepa*, critically discuss the literature presenting their antimicrobial properties, and discuss potential mechanisms of action and gaps in research. A refined literature based approach with in-text citations will be followed to provide scientific accuracy and coherence.

2. Phytochemical Composition

2.1 *Raphanus sativus* (Radish)

Among the numerous phytochemicals found in *Raphanus sativus* are glucosinolates, isothiocyanates, phenolic compounds, flavonoids, and anthocyanins, especially in red and purple ones (Barillari *et al.*, 2006; Manivannan *et al.*, 2019).

Radish roots and leaves are also known to have glucosinolates like glucoraphasatin and glucoraphenin. When tissues are disrupted, these compounds are hydrolyzed by enzyme myrosinase to give isothiocyanates, nitriles and thiocyanates which are biologically active (Fahey *et al.*, 2001). Some phenolic acids such as ferulic, p-coumaric, and caffeic also have been found and play a role in antioxidant and antimicrobial properties (Park *et al.*, 2016).

2.2 *Brassica rapa*

The genus *Brassica rapa* includes various subspecies that are eaten in different parts of the globe, including turnip, pak choi and Chinese cabbage. It is mainly characterized by glucosinolates (e.g., gluconapin, glucobrassicinapin), flavonoids, carotenoids, and vitamins (Cartea *et al.*, 2011; Kim *et al.*, 2015).

Quercetin and kaempferol along with their glycosides are all common in the leaves and stems of *B. rapa*. These substances are antimicrobial, anti-inflammatory and antioxidant (Podsedek, 2007). Also, products of glucosinolates breakdown, such as isothiocyanates, are believed to be the significant contributors of antimicrobial actions (Avato *et al.*, 2013).

2.3 *Allium cepa* (Onion)

In table (1) *Allium cepa* is characterized by a high content of organosulfur compounds, flavonoids, and phenolic acids. Sulfur-containing compounds such as cysteine sulfoxides (e.g., alliin) and their degradation products (thiosulfinates and sulfides) are responsible for onion's characteristic odor and biological activity, (Lanzotti, 2006).

Quercetin and its derivatives are the predominant flavonoids in onion, particularly in the outer dry skins, where concentrations are significantly higher than in the edible bulb (Griffiths *et al.*, 2002). These compounds have been associated with broad-spectrum antimicrobial and antioxidant effects (Slimestad *et al.*, 2007).

Table 1. Comparative overview of major phytochemicals and antimicrobial activity of *Raphanus sativus*, *Brassica rapa*, and *Allium cepa*.

Plant species	Dominant phytochemicals	Primary antimicrobial targets	Overall antimicrobial activity
<i>Raphanus sativus</i>	Glucosinolates, isothiocyanates, phenolic acids, flavonoids	<i>Staphylococcus aureus</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i>	Moderate to strong antibacterial; moderate antifungal
<i>Brassica rapa</i>	Glucosinolates, isothiocyanates, flavonoids, carotenoids	<i>Listeria monocytogenes</i> , <i>Salmonella enterica</i> , <i>Bacillus subtilis</i>	Moderate antibacterial; limited antifungal
<i>Allium cepa</i>	Organosulfur compounds, flavonoids, phenolic acids	<i>Staphylococcus aureus</i> , <i>E. coli</i> , <i>Helicobacter pylori</i> , <i>Candida albicans</i>	Strong broad-spectrum antibacterial; moderate antifungal

3. Antimicrobial Activity

3.1 Antimicrobial Activity of *Raphanus sativus*

Several studies have demonstrated the antimicrobial potential of *R. sativus* extracts against Gram-positive and Gram-negative bacteria, as well as certain fungi. Methanolic and aqueous extracts of radish roots and leaves have shown inhibitory effects against *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa* (Otsuki *et al.*, 2010; Manivannan *et al.*, 2019).

Isothiocyanates derived from glucosinolates are believed to be the primary antimicrobial agents, acting through disruption of microbial cell membranes and inhibition of essential enzymes (Dufour *et al.*, 2015). Variations in antimicrobial activity have been linked to cultivar type, plant part used, and extraction method.

3.2 Antimicrobial Activity of *Brassica rapa*

Extracts from *B. rapa* have exhibited antimicrobial activity against a range of foodborne and clinical pathogens. Studies report inhibitory effects against *Listeria monocytogenes*, *Salmonella enterica*, and *Bacillus subtilis* (Avato *et al.*, 2013; Kim *et al.*, 2015).

The antimicrobial efficacy of *B. rapa* is often attributed to isothiocyanates produced from glucosinolate hydrolysis. These chemicals may enter into the cells of the microbes and disrupt metabolic activities causing their growth to be inhibited or cell death may occur (Fahey *et al.*, 2001).

B. rapa Extracts have exhibited antimicrobial activity against a range of foodborne and clinical pathogens. Studies report inhibitory effects against *Listeria monocytogenes*, *Salmonella enterica*, and *Bacillus subtilis* (Avato *et al.*, 2013; Kim *et al.*, 2015).

The *Allium cepa* has been biologically researched extensively in terms of antimicrobial properties. Isolated compounds and onion extracts have been shown to be active against bacteria including *Staphylococcus aureus*, *Escherichia coli*, *Helicobacter pylori* and fungi including *Candida albicans* (Griffiths *et al.*, 2002; Lanzotti, 2006).

Sulfur-containing compounds, especially thiosulfinate are regarded as the primary antimicrobial agents, which have their effect due to the interaction with thiol-containing proteins and enzymes in the cells of microbes (Ankri and Mirelman, 1999). Flavonoids like quercetin could have a synergistic effect since they disrupt the walls of the cell and prevent the production of nucleic acid.

4. Antimicrobial Action mechanisms.

It is imperative to understand the processes involved in the antimicrobial activities of the plant-

derived compounds to make rational use of these compounds in pharmacognosy and microbiology. The antimicrobial activity of the phytochemicals present in *Raphanus sativus*, *Brassica rapa* and *Allium cepa* occurs with a variety of mechanisms, usually overlapping and all, but not limited, to microbial structure, metabolism and genetic regulation, (fig. 1).

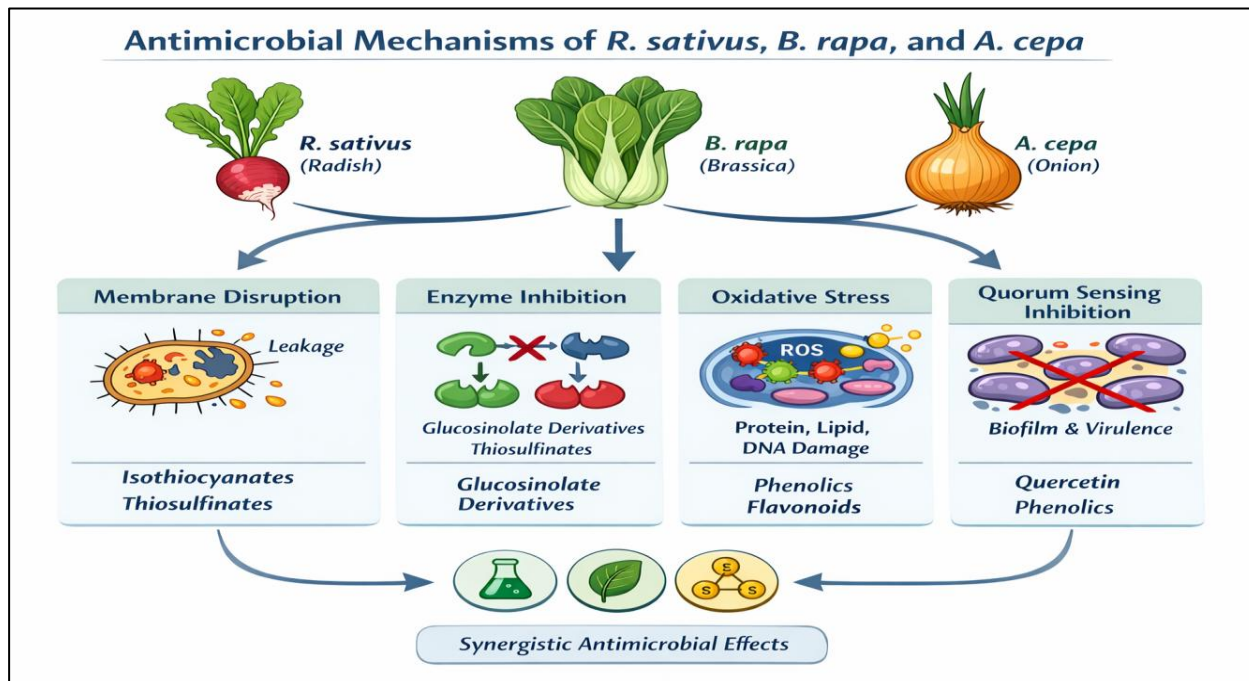


Fig (1): Demonstrate antimicrobial action of the plants in question.

4.1 Membrane Disruption and Permeability Alteration

Glucosinolates to isothiocyanates in *R. sativus* and *B. rapa* are highly electrophilic and are easily reactive with the microbial cell membranes. These compounds break membrane integrity by reacting with membrane proteins and phospholipids to cause increased membrane permeability, intracellular content leakage, and subsequent cell lysis (Dufour et al., 2015). Gram-positive bacteria are also more prone as they do not have an outer membrane, but some isothiocyanates may enter the Gram-negative bacterial envelope.

4.2 Enzyme Inhibition and Interference with Metabolism.

The compounds of sulfur in *A. cepa*, especially thiosulfinates suppress microbial growth by reacting with thiol (-SH) functionalities of vital enzymes of energy metabolism and DNA replication (Ankri & Mirelman, 1999). This is an irreversible inhibition of enzymes that affects central metabolic pathways causing a bacteriostatic or bacteriocidal effect. Other comparable enzyme-targeting strategies have been suggested based on isothiocyanates, which are able to inactivate dehydrogenases and other important metabolic enzymes.

4.3. Oxidative Stress and Redox Imbalance.

Phenolic acids and flavonoids occurring in all the three species have the ability to cause oxidative stress in microbial cells. These compounds damage proteins, lipids and nucleic acids by either generating reactive oxygen species or disrupting antioxidant defense systems (Cowan, 1999). Oxidative damage which builds up leads to growth inhibition and death especially in fungi and Gram-positive bacteria.

4.4 Effects on Quorum Sensing and Genetic Material.

Some flavonoids have been reported to interfere with the nucleic acid synthesis and action by intercalating with the DNA or by inhibiting topoisomerases (Slimestad et al., 2007). Also, phenolics of plants can interfere with quorum sensing, which decreases the production of

virulence factors as well as biofilm that are essential in pathogenicity and resistance to antibiotics in microbes.

5. Factors Affecting Antimicrobial activity.

The antimicrobial activity of the plant extracts depends on various factors, and they include plant variety, growth conditions, maturity, and post-harvest processing. Solvent of extraction and procedure of extraction also are important variables in the yield and the activity of phytochemicals (Dai and Mumper, 2010).

Combination of phytochemicals can increase or decrease antimicrobial effects and synergy, and vice versa. The method of extraction and testing is still not standardised in all studies and differing results cannot be compared.

6. Comparative Phytochemical-Antimicrobial Spectrum Analysis.

A larger overview of the key phytochemicals and antimicrobial profiles of *Raphanus sativus*, *Brassica rapa* and *Allium cepa* is given in Table 2 to allow a more precise pharmacognostic and microbiological comparison. This table combines known target microorganisms, plant areas investigated and relative antimicrobial potency that enables cross species analysis when discovering natural product drugs.

Table 2. Extended comparative analysis of phytochemicals and antimicrobial spectrum of *Raphanus sativus*, *Brassica rapa* and *Allium cepa*.

Plant species	Major phytochemical classes	Key bioactive compounds	Plant part(s) studied	Target microorganisms	Antimicrobial spectrum & relevance
<i>Raphanus sativus</i>	Glucosinolates, isothiocyanates, phenolic acids, flavonoids, anthocyanins	Glucoraphasatin, glucoraphenin, sulforaphene, ferulic acid	Roots, leaves, seeds	<i>Staphylococcus aureus</i> , <i>Bacillus subtilis</i> , <i>Escherichia coli</i> , <i>Pseudomonas aeruginosa</i> , <i>Candida</i> spp.	Moderate–strong antibacterial (especially Gram-positive); moderate antifungal; promising for foodborne pathogen control
<i>Brassica rapa</i>	Glucosinolates, isothiocyanates, flavonoids, carotenoids, phenolics	Gluconapin, glucobrassicinapin, kaempferol, quercetin	Leaves, stems, seeds	<i>Listeria monocytogenes</i> , <i>Salmonella enterica</i> , <i>Bacillus subtilis</i> , <i>E. coli</i>	Moderate antibacterial; limited antifungal; relevant for food safety and preservation applications
<i>Allium cepa</i>	Organosulfur compounds, flavonoids, phenolic acids	Alliin, thiosulfinates, diallyl sulfides, quercetin, quercetin glycosides	Bulbs, outer skins	<i>Staphylococcus aureus</i> , <i>E. coli</i> , <i>Helicobacter pylori</i> , <i>Klebsiella pneumoniae</i> , <i>Candida</i>	Strong broad-spectrum antibacterial; moderate antifungal; reported activity

				<i>albicans</i>	against resistant strains and biofilms
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Such a comparative analysis demonstrates that antimicrobial profiles of the three species are different but complementary to each other. Members of Brassicaceae family depend on glucosinolate derived isothiocyanates, and *A. cepa* has extended antimicrobial activity, owing to highly reactive sulfur compounds, which work in synergy with flavonoids. Their relevance is especially that of selecting pharmacogenostic diets and microbiological targeting of targeted pathogen groups.

7. Conclusion

This review brings out a huge pharmacognostic and microbiological potential of *Raphanus sativus*, *Brassica rapa*, and *Allium cepa* as sources of natural antimicrobial agents. All the evidence shows that these commonly consumed vegetables have varied and powerful phytochemical profiles with the capacity to prevent a wide spectrum of pathogenic microorganisms. The antimicrobial effect on *R. sativus* and *B. rapa* is mostly explained by the presence of glucosinolates and their hydrolysis products, especially isothiocyanates, which have effects of disrupting the membrane and inhibiting the enzyme. Conversely, antimicrobial activity of *A. cepa* is broad-spectrum and strong, which is highly contributed by reactive organosulfur compounds with the assistance of flavonoid compounds including quercetin.

Comparative analysis shows that the all three species show an antibacterial activity against common foodborne and clinical pathogens, but *A. cepa* is more consistent against repeat Gram negative bacteria and fungi, including those related to antimicrobial resistance. These results demonstrate that selection of plant species, phytochemical profile and use of plant parts are important in producing useful natural antimicrobials.

Although promising in in vitro studies, transformation of these plant-derived compounds into an actual clinical or industrial use has not been achieved due to limitations in the variability of phytochemical content, non-standardisation, and limited in vivo and clinical research. Future studies are to focus on the comprehensive in vivo studies that are designed properly, toxicity and pharmacokinetic studies, and investigation of synergistic interactions with standard antibiotics. These attempts will be critical in justifying the therapeutic significance of these plants as well as developing their usage in pharmacognosy, microbiology, food conservation and in the discovery of antimicrobial drugs.

It is evident in the literature that *Raphanus sativus*, *Brassica rapa*, and *Allium cepa* are good sources of phytochemicals that have a high potential of antimicrobial use. The antimicrobial activity of *R. sativus* and *B. rapa* is mainly due to glucosinolates and its derivatives, fauna in *A. cepa* is mainly due to sulfur-containing compounds and flavonoids.

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