

SPICES AND IMMUNITY: THE SCIENCE BEHIND THE FLAVOUR

EDITION: VOLUME 02, ISSUE 09, - September 2026



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Spices and Immunity: The Science behind the Flavour

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ISSN No.: 3107-9903

Frequency: Monthly

Month: August

Volume- 2, Issue- 9

India is universally recognized as the "Home of Spices," possessing a botanical and agricultural heritage that has shaped global trade, culinary traditions, and medicinal practices for millennia. Of the 109 spice varieties recognized by the International Organization for Standardization (ISO), India actively cultivates over 75, making it the undisputed global leader in spice production, consumption, and export (Spices Board India, 2025). Total production was 12.48 million tonnes in 2023-24 and is estimated at 11.99 million tonnes for 2024-25. Of the 52 spices grown in the country, commercial cultivation is concentrated in a few crops, namely chilli, turmeric, black pepper, cardamom, ginger and the seed spices, which matter in both domestic and international trade (Nybe *et al.*, 2007). Spices are also a major export earner. Exports reached an all-time high in 2024-25 at 17.99 lakh tonnes, worth US\$4,722.65 million. In 2025-26, exports were 17.34 lakh tonnes, worth US\$4,430.90 million, and chilli (27%), cumin (12%) and spice oils and oleoresins (12%) led the export basket by value (Spices Board India, 2026).

The human immune system is a remarkably complex network of cells, tissues, and organs that work in unison to defend the body against attacks by "foreign" invaders. These invaders include bacteria, viruses, parasites, and even fungi. In the

modern era, while pharmaceutical interventions are vital, there has been a significant resurgence in exploring the prophylactic and therapeutic potential of natural substances. Among these, culinary spices stand out not just for their flavor profiles, but for their dense concentrations of bioactive compounds.

Spices are low-volume, high-value crops. They add taste, colour and aroma to food, and they have long been used as appetizers and preservatives (Srinivasan, 2005). Many spice compounds also have antimicrobial activity against food-borne pathogens and spoilage organisms, which helps explain their traditional use in food preservation (Tajkarimi *et al.*, 2010).

Beyond the kitchen, spices have a long record in traditional medicine, including Ayurveda and Traditional Chinese Medicine. Experimental studies in animals and humans have documented digestive stimulant, hypolipidemic, antidiabetic, antioxidant, and anti-inflammatory effects (Srinivasan, 2005). Reviews of spice antioxidants link these compounds to their potential effects on human health (Yashin *et al.*, 2017). There is also growing interest in their chemopreventive potential, since several spice constituents have antioxidant and anti-inflammatory activities relevant

to tumour promotion (Surh, 2002; Kaefer & Milner, 2008). Because of these bioactive properties, spices are increasingly regarded as functional foods (Tapsell *et al.*, 2006).

Each spice crop contains a characteristic set of phytochemicals that contribute to health and to the functioning of the immune system. Curcumin in turmeric, gingerols and shogaols in ginger, capsaicin in chilli, piperine in black pepper, allicin in garlic and thymoquinone in black cumin are among the best studied of these bioactive principles (Zhenget al., 2016). Through such compounds, spices have been reported to act as antioxidants, antimicrobials, antidiabetic and anti-mutagenic agents, anti-inflammatory compounds and digestive stimulants (Srinivasan, 2005; Kaefer & Milner, 2008).

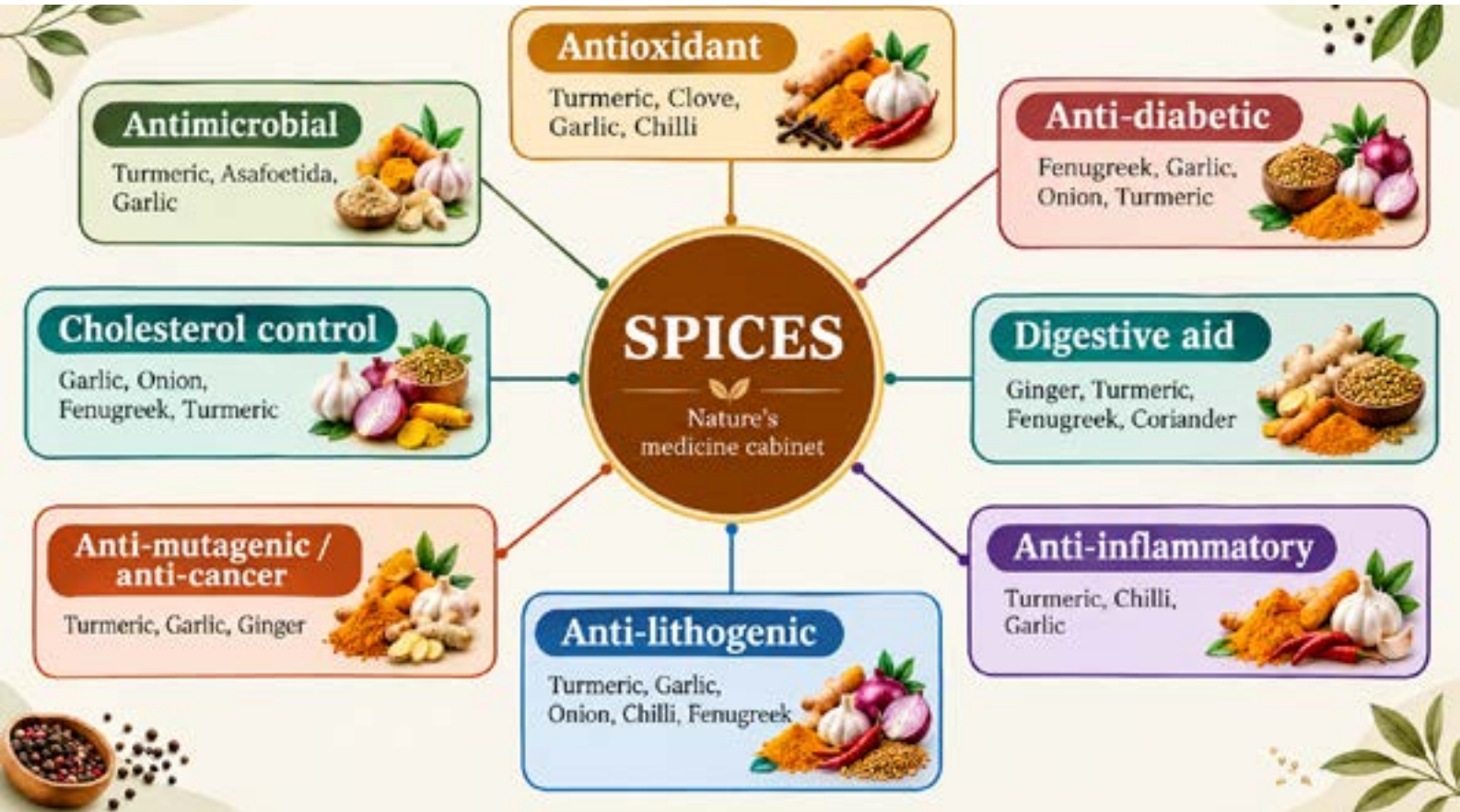
The immune system defends the body against foreign invaders such as bacteria, viruses, fungi, parasites, and their toxins, which cause common seasonal infections including colds, coughs, and fevers. Diet is one of the modifiable factors that influences immune competence, and a number of herbs and spices have demonstrated immunomodulatory activity (Beswa & Ndlovu, 2021). Ginger, for example, exerts antioxidant and anti-inflammatory effects through the Nrf2 and NF- κ B signalling pathways, shifting the balance of pro- and anti-

inflammatory cytokines (Ayustaningwarno et al., 2024). Curcumin likewise modulates the activity of macrophages, lymphocytes and natural killer cells (Zheng et al., 2016).

Taken together, spices possess a broad range of bio-functions whose combined action may support the body's defences. It should be noted, however, that much of this evidence comes from in vitro and animal studies, and that well-controlled human trials remain limited for most spices.

Spice crop	Phyto-nutrients	Spice crop	Phyto-nutrients
Chilli	Capsaicin	Nigella	Thymoquinone
Turmeric	Curcumin	Sweet flag	Acorin
Ginger	Gingerol	Aniseed	Anethole
Black pepper	Piperine	Nutmeg	Myricetin
Cardamom	Cineole	Coriander	Linalool
Clove	Eugenol	Saffron	Cicrocrosin
Asafoetida	Ferumine	Fenugreek	Diosgenin
Ajwain	Thymole	Cumin	Cuminol
Cinnamon	Cinnamaldehyde	Fennel	Limone

Table 1. Some of the specific phyto-nutrients available in Spice crops



Black pepper has traditionally been used for pain relief and for complaints such as rheumatism, influenza, the common cold and indigestion, and it is also recognized as an antimicrobial agent. Ginger has a long history in herbal medicine for fever, diabetes, liver disorders, bronchitis, hypertension, tuberculosis and sinus complaints. Turmeric has been used for centuries for rheumatism, body ache, skin diseases, intestinal worms, diarrhoea, intermittent fevers, constipation, urinary discharges, leukoderma and dental problems, as well as for digestive complaints such as indigestion, ulcers, dyspepsia, acidity and colic, and for inflammatory disorders including arthritis, colitis and hepatitis. Garlic has been used for fevers, liver disorders, diabetes, tuberculosis, rheumatism, dysentery and hypertension (Anupam et al., 2018). Other spices have comparable reported effects through antimicrobial, anti-inflammatory and antioxidant activities.

Free radicals arise from normal metabolic processes within the body and from external sources such as ionizing radiation, cigarette smoke, air pollutants and industrial chemicals. They are highly reactive and short-lived, but within that time they can damage DNA, proteins and membrane lipids. When the generation of reactive species exceeds the capacity of the body's defence systems, the resulting oxidative stress can cause mutations and cumulative cellular damage. Oxidative stress has been implicated in cardiovascular disease, stroke, cancer, arthritis, respiratory disease, neurodegenerative conditions such as Parkinson's disease, and ageing (Pham-Huy et al., 2008).

Antioxidants, also termed free radical scavengers, limit this damage by donating an electron or a hydrogen atom to the unstable radical, converting it into a comparatively stable, non-reactive species while the antioxidant itself becomes a low-reactivity radical that is subsequently regenerated or safely eliminated. The body's antioxidant defences comprise enzymatic systems such as superoxide dismutase, catalase and glutathione peroxidase, together with dietary antioxidants including vitamins C and E, carotenoids and polyphenols (Pham-Huy et al., 2008).

Spices are more than just flavor enhancers; they are concentrated pharmacies in our kitchens. By understanding the role of compounds like Curcumin, Gingerol, and Allicin, we can move from accidental consumption to intentional nourishment. Incorporating a variety of these spices—especially in synergistic combinations—provides a low-cost, high-impact strategy for maintaining immune homeostasis. The antioxidant properties of spices are relevant to the oxidative modification of low-density lipoprotein cholesterol an early step in atherogenesis. The principal

antioxidant constituents include flavonoids and phenolic amides from black pepper, capsaicin and capsaicinol from chilli, eugenol and gallates from clove, gingerols and diarylheptanoids from ginger, and curcumin from turmeric. Several of these compounds also show anti-mutagenic activity; curcumin from turmeric and the organosulfur compounds of garlic are notable examples (Srinivasan, 2005). Foods with higher Oxygen Radical Absorption Capacity (ORAC) values may be more effective at neutralizing free radicals.

Combination	Target Benefit	Biological Reason
Turmeric + Black Pepper	Systematic inflammation	Piperine inhibits the metabolism of Curcumin, keeping it in the bloodstream longer.
Garlic + Ginger	Respiratory defence	Combined antiviral and anti-inflammatory action that targets the mucous membranes.
Cinnamon + Clove	Pathogen shield	Overlapping antimicrobial profiles that cover a wider range of bacteria and fungi
Spice + Healthy Fat	Nutrient absorption	Fat-soluble compounds (like those in turmeric and pepper) require lipids for transport.

Table 2. Synergistic Effects: The Power of Combinations

The concept of synergy is where nutrition becomes "medicine." In nature, compounds rarely work in isolation.

FOOD ITEM	ORAC values
Egg Whites	10
Beef Steak - Meat	10
Egg Yolk	20
Egg, Whole	20
Instant White Rice, Cooked	30
Milk, 2% Fat	50
Fried Chicken Without Skin, Frozen – Meat	60
Fried Chicken With Skin, Frozen Meat	50
Fried Chicken Without Skin, Frozen - Meat	60

FOOD ITEM	ORAC values
Cabbage, Boiled	856
Cauliflower, Raw	870
Eggplant, Raw	932
Mangos, Raw	1300
Broccoli, Raw	1510
Red Grapes, Raw	1837
Cashews, Nuts	1948
Pomegranates, Raw	4479
Garlic, Raw	5708
Saffron Spice, Whole	20580

FOOD ITEM	ORAC values
Fried Chicken With Skin, Frozen - Meat	50
Honey	130
Watermelon, Raw	142
McDonald's Crispy Chicken Sandwich	180
Pizza Hut Cheese Pizza	170
Green Peas, Canned	120
Papaya, Raw	300
White Tea, Bottled	264
Green Tea, Bottled	520
Oyster Mushrooms, Raw	664
Butter	730

FOOD ITEM	ORAC values
Garlic, Raw	5708
Saffron Spice, Whole	20580
Paprika Spice	21932
Black Pepper Spice	34053
Ginger Spice, Ground	39041
Cumin Seed Spice	50372
Basil Spice, Dried	61063
Allspice, Ground	100400
Dried Vanilla Bean	122400
Turmeric Spice, Ground	127068
Ground Cinnamon Spice	131420
Ground Cloves Spice	290283

Source: ORAC values database 2020

Conclusion

Spices contribute to human health through several mechanisms, acting as antioxidants, anti-mutagens, anti-inflammatory and antimicrobial agents, and as modulators of immune function, with reported antiviral and cancer-preventive potential. Because each spice contains a distinct combination of bioactive principles, and because these may act synergistically when spices are consumed together, a well-spiced diet is likely to make food not only more flavourful but also more

healthful.

The evidence reviewed here nevertheless comes largely from in vitro systems and animal models. Well-designed clinical trials in humans are needed to establish effective doses, bioavailability, safety at dietary and supplemental levels, and possible interactions with medication. Further work is also required on the nutritive and phytochemical composition of the lesser-studied spices, and on how growing conditions, post-harvest handling, processing and cooking affect the retention of their bioactive constituents.

Generating such evidence would allow the health-promoting properties of spices to be incorporated into dietary guidelines and public-health strategy on a sound scientific footing, and would strengthen the position of spices as functional foods in both domestic and export markets.

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