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Spices technologies for maximum nutraceutical, environmental and social benefits

Spices are high value and low volume, export-oriented commodities, commonly used for flavouring and seasoning of food and beverages. India is the world's largest producer, consumer, and exporter of spices; the country produces about 75 of the 109 varieties listed by the International Organization for Standardization (ISO) and accounts for half of the global trading in spices. The consumption of spices is growing in the country with increase in purchasing power. It is envisaged that everyone in India would be consuming one spice or the other with a high per capita consumption. This may increase further due to rapid urbanization which needs spices as natural food preservatives. Growing demand from the emerging segment of nutraceuticals is driving the global consumption of Indian spices further at a time when the country is straining to meet the needs of the traditional food sector. Though spices contains diverse array of phytochemicals, the nutraceutical preparation often revolve around few major bioactive metabolites. Non-traditional use of spices including nutraceuticals now accounts for nearly 15% of spice production in India, estimated at 50 lakh tonne a year.

THE enhanced productivity witnessed across spice crops is a result of adoption of improved cost-effective technologies which can improve the competitiveness of Indian spices in the global markets. India's spice industry has been one of the Nation's great horticultural success stories. Developing new innovative technologies for commercial release that open new markets, is essential to build a stronger Indian Spice sector. Researchers are working to develop new spice technologies with desirable production qualities and industrial use that will help capture the market and revitalize this industry.

Industrial use

The demand of spice oils and oleoresins is increasing mostly due to enhanced use in food and beverage industries. Spice oils are the volatile components present in most spices and provide the characteristic aroma of the spices. Spice oleoresins represent the complete flavour profile of the spice. It contains the volatile as well as non-volatile constituents of spices. The standard of quality expected in a spice oil or oleoresin will differ depending on its end uses. Therefore, these oils are custom-made to meet the exact requirement of the user. India is a leading exporter of spice oils to West Europe, USA and the Far East.

Nutraceuticals in spices

In addition to nutrients such as vitamins, minerals, amino acids, peptides, and some fatty acids, there are other specific bioactive compounds that can be considered as nutraceuticals: enzymes, pre- and pro-biotics, coenzyme Q10, glucosamine, chondroitin, etc., as well as many phytochemicals (polyphenols, sulphur-containing compounds, alkaloids, terpenoids, etc.). Additionally, nutraceuticals can be classified into potential and/or established nutraceuticals according to their proven beneficial effects as demonstrated in either preclinical or clinical studies. In addition to their sensory properties, the spices in our diet are rich sources of different phytochemicals with putative beneficial effects e.g. antioxidative, anti-inflammatory, chemopreventive, antimutagenic, immune-modulatory properties.

Spices like turmeric, ginger, black pepper, fenugreek, coriander, etc., contain considerable quantity of biologically active specific metabolites with numerous biological functions. Curcumin in turmeric; capsaicin in red pepper; piperine in black pepper; [6]-gingerol in ginger; saponin in fenugreek are immensely valuable in health care with their multiple physiological effects.

Better varieties

Over the past few decades, ICAR-Indian Institute of Spices Research and ICAR-All India Co-ordinated Research Project on Spices (involving State Agricultural Universities) have released several spices with focus on spice industry, greater resilience to Indian conditions, and improved attributes and performance.

Varieties for industrial extraction

Spice oleoresins are largely used for food processing and flavouring industries like meat canning, sauces, soft

drinks, pharmaceutical preparations, perfumery and soap, tobacco, confectionery, and bakery. Most of the released varieties are aimed for higher yield and disease tolerance. Some of the varieties released in India with specific quality attributes with high essential oil and oleoresins are as follows:

Crop	Industrial extraction	Variety
Black pepper	High essential oil	Sreekara (7%), Subakara (6%), Panniyur 9 (5%)
	High oleoresin	PLD 2 (15.45%)
Small cardamom	High essential oil	Appangala 1 (8.7%)
Turmeric	High essential oil	Sudarsana, Suvarna (7.0 %)
Ginger	High essential oil	KAU Athira, KAU Karthika (3%)

Sreekara: a variety for high essential oil

Varieties for nutraceuticals

Though spices contains diverse array of phytochemicals, the nutraceutical preparation often revolve around few major bioactive metabolites. In addition to their sensory properties, the spices in our diet are rich sources of different phytochemicals with putative beneficial effects e.g. antioxidative, anti-inflammatory, chemopreventive, antimutagenic, immune-modulatory properties. Spices like turmeric, ginger and black pepper contains considerable quantity of biologically active specific metabolites with numerous biological functions–curcumin in turmeric; piperine in black pepper; [6]-gingerol in ginger.

Crop	Nutraceutical attribute	Variety
Black pepper	High piperine (> 5%)	IISR Malabar Excel, Panniyur 2, Panniyur 9
Turmeric	High curcumin (> 5%)	IISR Prathiba, IISR Pragati, Megha Turmeric, Rajendra Sonia
Ginger	High gingerol	KAU Karthika

Varieties for natural colour

The colours that originate from any edible sources like flowers, fruits, vegetables and plants are called natural food colourants. They impart colour when added to food or drink. The natural colourant is obtained by physical and/or chemical extraction resulting in a selective extraction of the pigments relative to the nutritive or aromatic constituents. Some spices are also used as natural colourants.

Anthocyanins

Anthocyanins are water soluble pigments responsible for the attractive red, purple and blue colours of many flowers, fruits and vegetables. The colour varies with respect to the pH, it is reddest in strongly acidic conditions and become bluer as the pH rises. Used in drinks, jams and sugar confectionery. Anthocyanins are present in kokum (Garcinia indica), which is a potential source of a natural food colourant. The ripe kokum fruit is coloured either dark purple or red tinged with yellow. It is widely available and has been traditionally used as a food ingredient without apparent toxic effects; it could be a potential source of anthocyanins.

Curcumin

Turmeric is a well-known spice, used widely in cookery. Its pigment, curcumin, is oil soluble and sensitive to light, but has good heat stability. It gives a lemon-yellow shade in food systems. Its applications include pickles, soups and confectionery.

Lemon yellow	Bright orange	Dark orange
Rajapuri, Narendra Haldi 98	IISR Prathiba, IISR Pragathi, Duggirala Red, Rajednra Sonia, Punjab Haldi 1	Varna, Suvarna, Megha Turemric 1

High and low curcumin turmeric varieties

Spices varieties rich in flavour compounds

Spices were always valued exclusively for their aroma and flavour. The flavour of each spices is contributed by secondary metabolites. The flavour compounds responsible for distinct aroma in different spices are:

Crop	Variety	Flavour compounds
Black pepper	IISR Malabar Excel, Panniyur 2, Panniyur 9	> 5% piperine
Cardamom	PV1, ICRI 6, ICRI 7, Appangala 1	> 25% 1, 8-cineole, 45% alpha-terpinyl acetate

Crop	Variety	Flavour compounds
Ginger	IISR Vajra, Suprabha	Zingiberene content (>30 %)
Turmeric	IISR Prathiba, IISR Pragati and Duggirala Red	>35% Turmerone
	Narendra Haldi 98, Megha Turmeric 1	>19% Zingiberene
Nutmeg	IISR Keralashree, IISR Vishwasree	Myristicin (>9%), Sabinene (> 35%)
Cinnamon	IISR Navashree, IISR Nithya shree	Cinnamaldehyde (> 50%)

Varieties for processing industries

Spices are value added by different types of processing, where black pepper is processed to white pepper, fresh ginger as ginger candy and nutmeg seed for nutmeg butter. The following are some of the varieties suitable for processing:

Crop	Attribute	Varieties
Black pepper for white pepper	Bold berries, pericarp seed ratio	IISR Girimunda, Panniyur 1 and Panniyur 3
Ginger for candy	Low to medium in fibre (4 – 5%)	Subrabha, IISR Varada and IISR Vajra
Nutmeg for nut butter	Nut butter (25%)	IISR Vishwashree, IISR Keralashree

Better technologies

Quality planting material

Protocols for micro-propagation, micro-rhizome production and improved vegetative propagation methods of spice crops were standardized, popularized for disease free production of nucleus planting materials of improved varieties throughout the country. The pro-tray based transplanting technique in turmeric and ginger by using single bud sprouts (5 g) raised in soil-less nursery mixture, reduces the seed rhizome requirement by one-fourth and saves considerably the cost on seed which otherwise contributes to 60% of production cost. This technology can address some of the serious concerns of diseases in the seedling stage and same method can be followed in black pepper also for production of disease-free planting materials.

Transplanting in turmeric

The continuous demand for quality planting material in black pepper created a novel idea of producing more orthotropic shoots on vertical mesh columns filled with composted cocopeat and vermicompost mixture fortified with bio-control agents under protected conditions. In this method, three types of planting material i.e. single node cuttings, top shoots with lateral branch (use of top shoots for field planting is having advantage of producing fruit bearing branch from the base of the support and start yielding early) and laterals or plagiotropes, which are used for production of bush pepper can be produced simultaneously in large numbers.

Soil health management

Majority of soils in the spice growing areas are encountering fertility issues due to acidity, nutrient imbalances, and deficiencies of secondary and micronutrients that becomes yield limiting. Crop specific, soil pH based micronutrient mixtures for foliar application in spice crops offer a way out from the production limiting factor induced by micronutrient deficiency. The application of micronutrient guarantees 10 to 25% increase in yield besides improvement in product quality. An innate advantage of these mixtures is that they can also be used in organic agriculture and therefore are benign and environment friendly. Institute has also developed mixed and intercropping system models for doubling farmers' income; integrated site-specific nutrient management for sustainable soil heath for spice based cropping systems; organic production packages; and demonstrated the same in major spice tracts for increasing productivity.

Irrigation of black pepper vines around the basin from March to May @ 50-80 litre/vine at an interval of 15 days can markedly enhance spike length, number of spikes, oleoresin content and berry yield. This technology promotes uniform spike initiation and reduces the spike shedding due to late monsoon and guarantees good crop. A simple technique of hormone treatment was developed to split open nutmeg fruits without exposure to soil to prevent aflatoxin contamination in nutmeg.

Plant health management

IPM technologies involving spraying of low-risk green labelled insecticides such as chlorantraniliprole, flubendiamide, spinosad for effective control of shoot borer in ginger, and turmeric and cardamom thrips reduces the risk to the environment. IDM protocols involving $CaCl_2$ for the control of bacterial wilt of

Crop specific micronutrient mixture.

ginger was standardized and demonstrated across India.

Development of diagnostics for virus infecting spices by loop-mediated isothermal amplification (LAMP) and real-time LAMP based assays have been developed and deployed for quick and sensitive detection of virus diseases of black pepper, cardamom and ginger. The technology can be used for certification of mother plants/planting materials of black pepper for freedom from viruses. A strain specific and sensitive technique based on Real Time Loop Mediated Isothermal Amplification (Real Time- LAMP) was developed for detecting race 4 strain of *Ralstonia solanacearum* causing bacterial wilt in ginger.

Technologies like, *Pochonia chlamydosporia*, a biocontrol agent against nematodes, use of an entomopathogenic fungus, *Lecanicillium psalliotae*, for controlling the cardamom thrips etc., offers immense scope for reducing the pesticide use in spice based cropping systems. PGPR formulations for spices identified across several spice crops are gaining attention in the wake of the persistent and strong demand for effective environment friendly strategies for enhancing crop health. For ginger, the formulation consists of *Bacillus amyloliquefaciens*, a PGPR specific to ginger, and for black pepper, the PGPR is a consortium of three PGPR specific to black pepper, namely *Micrococcus luteus*, *Enterobacter aerogenes* and *Micrococcus* sp. The major advantages of the ecologically safe PGPR formulations include enhanced nutrient mobilization and nutrient use efficiency, increased growth, yield, and better tolerance to specific biotic stresses.

Seed coating using PGPR is a novel approach of coating efficient strains of PGPR on seeds/ seed rhizomes. The components consist of live PGPR, inert material and a binding agent. The coated seeds can be stored at the room temperature. Constraints like low germination, slow initial growth and high susceptibility to diseases can be addressed through this technology and can be easily adopted in spices like ginger, turmeric, tuber crops and seed spices.

Bio-agent input delivery

World's first encapsulation technology for smart delivery of beneficial microorganisms to crops developed and patented by the institute is expected to replace the conventional talc and liquid bio-fertilizers formulations. Any agriculturally important microorganism like N fixers, phosphorus solubilizers can be encapsulated and delivered to crops for enhanced growth promotion, soil nutrient solubilization/ mobilization and biocontrol. The capsules can be stored at normal temperature and has enhanced shelf life. The licensing of this technology on smart delivery of bio-agents (bio-control/ PGPRs) has helped in easy and effective reach of bio-agents reaching targeted crops in about 10% of spice growing areas.

Bio-capusles

Post-harvest technology

Post-harvest technologies for processing and value addition of spices were developed and adopted by farmers/ entrepreneurs for increasing income. Spices extracts were established as the most potent antioxidant and exploiting the same as a nutraceutical and anti-cancerous agent. ICAR-IISR has developed turmeric milk preparations, viz. ready-to-serve sterilized flavoured turmeric milk turmeric milk, instant mix powder with rich flavour and antioxidant properties, in collaboration with MILMA, Kozhikode, Kerala. The export of value-added products has happened across spice commodities and this development is favourable for strengthening value chain in spices, and realizing the profit margins from organizing production activities along the value chain.

Spice mix for golden milk

DNA barcoding has been put into use to detect the plant-based adulterants in traded spices such as black pepper powder, cinnamon, nutmeg, and turmeric at ICAR-IISR. DNA barcoding method could detect chilli as an adulterant in traded black pepper for the first time. At a time when food safety and quality of spices in the value chain is garnering more importance, this technology offers a tool for quality control along the value chain.

Conclusion

Our capability to address the challenges faced by spice sector directly depend on the technological options developed in response that are to be simple, cost-effective and farmer friendly. There is a great scope to improve the productivity of major spices by adopting technologies that will help to bridge the gap between potential yields realized in the research stations/progressive farmers' plots. Nurturing and improving sound techniques, technologies and innovations in the entire spices sector can help in surmounting the challenges posed by competing countries, and help in meeting the global market demands while ensuring a sustainable and equitable production model.

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