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REVIEW ARTICLE

Post-Harvest Management and Value Addition in Vegetable Crops

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Abstract
Horticultural production is reaching new heights every passing year. Presently, India is the second largest producer of vegetables after China. However, humongous postharvest losses and waste occur due to improper management and handling. Postharvest loss has been one of the main global challenges towards ensuring food security. This waste seems inhumane especially when tens of millions of people worldwide are suffering from hunger, malnutrition, under-nutrition and other chronic diseases while the food waste contributes to global warming as well. Fresh vegetables are highly perishable. Lack of proper transportation, especially temperature management during transit and storage further reduces their storability and marketing window. United Nations sustainable developmental goal 2 aims to reduce food losses by 50% by 2030. Several approaches like value addition particularly drying technology, temperature and storage atmosphere control, using edible coatings and different anti-senescent molecules like salicylic acid, nitric oxide, 1-methylcyclopropene, methyl jasmonate, polyamines, etc. have been undertaken world-wide to enhance storability of fresh vegetables. This review is an attempt to present a bird' eye view of postharvest losses and possible strategies for the management and reduction of losses in vegetables.
Keywords: Post-harvest management, vegetables, value addition.

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Introduction
Vegetables play a significant role in nutrition and food security. The presence of natural pigments in the form of bioactive compounds in vegetables provides many functional properties that help in preventing chronic diseases such as neurological, cardiovascular, cancer, diabetes and aging process (Koley *et al*., 2018). India is the second largest producer of vegetables in the world after China and produces 204.61 million tonnes of vegetables from an area of 11.35 million hectares (APEDA, 2023). The major states with higher contribution share are West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh and Andhra Pradesh (HORTSTAT, 2018). However, the quality and safety of vegetables reaching to consumer's doorsteps depend upon pre-harvest factors and post-harvest management practices throughout the value chain from field to plate. The most common cause of postharvest losses include rough handling, inadequate cooling and temperature maintenance, physical injuries, shriveling, pest damage, physiological disorders after harvest, inadequate packaging and lack of market information (Dhall, 2012). The lack of knowledge on pre-harvest management and poor postharvest processing leads to huge postharvest losses to the tune of 25 to 30% which amounts to approximately Rs. 1 lakh crores, while internationally is estimated at 750 billion US$ (Ghanghas *et al*., 2017; NAAS, 2019). Post-

harvest management and value addition assume greater significance as the global population continues to surge from 8 billion and is projected to reach 9 billion by 2037 and 10 billion by 2058. The major reasons for higher perishability in fresh horticultural crops are higher moisture content, soft texture, higher susceptibility to diseases and high metabolic rates. Spoilage and losses may also be attributed to insufficient awareness of effective postharvest practices, inadequate grading and packing, insufficient storage, and deficient transportation facilities (Jha *et al*., 2015; NABCONS, 2022). The losses also result in unnecessary emissions of greenhouse gases (FAO, 2016). The extent of post-harvest losses are as high as 50% some-times, which implies that more than half of the total produce never reaches the intended end consumers.

The diverse group of vegetables presents many nutritional and health benefits such as vitamins, minerals and dietary fiber. Vegetables belonging to different families are each a powerhouse of different phytochemicals which help to maintain good health and help in preventing many diseases. Cucurbits like bottle gourd, bitter gourd, cucumber, sponge gourd, pointed gourd, ridge gourd, ivy gourd; solanaceous vegetables like tomato, brinjal, chili; leguminous vegetables like Indian bean, French bean, broad bean, pea; leafy vegetables like spinach, amaranth, fenugreek, chenopodium, lettuce; cruciferous vegetables like cauliflower, cabbage, broccoli, radish; umbelliferae like carrot and tree vegetables like moringa. These can be used to prepare a number of vegetable-based processed products to reduce their waste and proper utilization which, therefore, needs additional focus on the development of infrastructure, storage and processing facilities (Singh & Singh, 2015; NAAS, 2019).

In view of poor and fragmented supply chain and lack of cold chain management facilities, the value addition is around a dismal 2.2%. The low-cost processing on a large scale is well suited for India to preserve the desired sensory qualities in processed vegetables. Among the various processing technologies, drying can be used as a valuable technology to reduce volume, preserve quality and enhance storability for longer period of time. Several drying technologies such as hot air-controlled drying, spray drying, freeze drying, infrared drying, superheated steam drying, osmotic dehydration, microwave drying, and hybrid drying methods are practiced. Notable among them are, freeze drying which is known to produce best quality dried produce and hot air drying which is used most commonly due to easy handling and cost efficacy. The major drawbacks in freeze drying are longer drying time and higher energy consumption which ultimately leads to higher per unit cost of the dried product. The entrepreneurs look for an intelligent, cost-effective drying system with good quality of dried product comparable to fresh produce. The selection of drying technique varies with the quality and quantity of raw material, availability of dryer, cost of operation, maintenance and operating easiness which ultimately determines the final quality of dehydrated product (Barrett & Lloyd, 2012; Ahmed *et al*., 2016; Waghmare *et al*., 2023). Minimal processing, edible coatings, modified atmosphere packaging, ethylene absorbents, essential oils, hurdle technology, optimum storage and preservation methods, use of 1-methylcyclopropene, polyamines, salicylic acid, nitric oxide, 6-benzylaminopurine, methyl jasmonate and other anti-senescent molecules have been found to be effective for increasing shelf life of fresh vegetables (Abe & Watada, 1991; Algeria *et al*., 2010; Singh *et al*., 2014; El-Ramady *et al*., 2015; Patrignani *et al*., 2015; Tapia *et al*., 2015; Elik *et al*., 2019; Yadav *et al*., 2022a,b).

Vegetable-based processed products have huge potential commercially mainly due to taste, health and nutritional benefits. ICAR-Indian Institute of Vegetable Research at Varanasi is a leading institute on vegetable research in India. Several vegetable-based processed products such as green chili powder, dehydrated okra, bitter gourd chips, instant bottle gourd kheer mix, Instant moringa soup mix and Instant moringa drink mix have been developed at IIVR (Singh & Singh, 2015; Singh *et al*., 2015b). These technologies have been patented and commercialized to entrepreneurs to reduce post-harvest losses and wastage. Presently, there is need to increase focus towards secondary agriculture to increase employment, income and reduce losses. This will surely act as a boost for value addition and promote self-reliance and agricultural start-ups.

Postharvest Losses

Several factors contribute to postharvest losses in vegetables. Vegetables should be harvested at the proper maturity stage to attain maximum quality. Harvesting of vegetables at pre or post-maturity stage and improper handling methods aggravate losses to a greater extent (Gustavsson *et al*., 2011; Kasso & Bekele, 2018; Etefa *et al*., 2022). Rough handling during and after harvesting can result in mechanical injuries (Miller, 2003). Typical industrial postharvest processing includes harvesting, sorting, grading and washing. Mechanical injuries like bruising, scarring, scuffing, cutting or puncturing the vegetables lower storability. Farmers after harvest use various types of packaging materials such as wooden baskets, gunny bags and plastic crates and produce is transported by mini-trucks or lorries. Increased use of corrugated cartons for local distribution of produce could be accomplished with improvement in the quality of boxes. The ventilated CFB box is found to be ideal for packaging and transportation of vegetables owing to comparably minimal bruising (Chakraborty & Chattopadhyay, 2018). Storage conditions significantly impact the longevity of stored vegetables. Optimal storage temperatures for vegetables slow down aging, softening, color changes, undesirable metabolic shifts, moisture loss and pathogen-related losses (Nunes, 2008). On-farm storage is required in remote and inaccessible areas of India to reduce losses of high perishable vegetables. Proper cold chain management includes immediate cooling after harvest and maintenance during transport. However, the non-availability of cold storage coupled with high cost and high energy requirements of refrigeration and the difficulty of installing and running refrigerated facilities in remote areas of India results in no use of refrigerated facilities in many parts of India. At a limited scale on trial basis, low-cost zero energy environmentally friendly cool chambers were fabricated from locally available materials, Pusa zero energy cool chamber (Pusa ZECC), which worked on the principle of evaporative cooling (Chakraborty & Chattopadhyay, 2018).

In developing countries, up to 23% of perishable foods spoil due to inadequate cooling (IRI, 2009). Strategic storage temperature in vegetables improves time management and allows for leisurely marketing and consumption. In developed countries, maintenance of cold storage temperature coupled with relative humidity throughout the entire supply chain of vegetables from farm to produce in modified and controlled storage conditions significantly extends shelf life. Conversely, inadequate storage facilities in developing countries remain a primary cause of postharvest losses (FAO, 2013). Transportation, especially in the context of globalized food trade, presents huge challenge. Long-distance transportation with poor refrigerated facilities can result in huge losses both in quality and quantity of vegetables particularly for fresh produce**.** Developed countries typically employ refrigerated vehicles for perishable food delivery. In contrast, inadequate transport and inefficient logistics in developing nations hinder proper preservation.

Additionally, vegetables often suffer from inadequate packaging and careless loading practices, sometimes being haphazardly tossed into vehicles. Proper packaging plays a pivotal role in mitigating losses and extending shelf life of fresh vegetables. Inferior quality packaging fails to protect produce adequately, hastening spoilage. Relevant studies in Sub-Saharan Africa and South Asia highlight concerning statistics: 46% of horticultural crops were packed in cloth bundles or large sacks, 31% in open baskets, and 8% had no packaging at all. Effective packaging and refrigerated transport significantly reduce losses. At retail, the absence of proper packaging further shortens shelf life, necessitating quick sales. Major challenges are cold chain management, non-availability of mechanized sorting/grading facility, non- availability of varieties suitable for processing and the complete value chain of vegetables (Kiaya, 2014).

The consumption stage spans period from consumers purchasing fresh vegetables to their actual consumption, but it's a phase where significant losses occur in the food supply chain. Nearly half of household food waste is mainly fruits and vegetables. Studies from FAO (2011) and WRAP (2008) suggest that fruit and vegetable waste constitutes around 39 to 40% of total household waste. The reasons behind consumer waste vary from over-purchasing and poor planning to inadequate home-storage management. The extent of waste depends on socio-cultural factors like gender, lifestyle, income and availability of home storage facilities (Porat *et al*., 2018). Postharvest losses in developed nations are primarily linked with consumer preferences especially stringent quality standards and safety for fruits and vegetables (FAO, 2011; FAO, 2015).

Post-harvest Management

Postharvest management includes a wide range of activities such as cleaning, washing, sorting, grading, disinfecting, packaging and storage at optimum temperature. Effective post-harvest management retains edible and nutritional quality of vegetables for longer period as well as supports the livelihood of farmers and the overall food supply chain. Sorting and grading involve the removal of diseased, damaged, over-mature, insect-infested, and rotten vegetables. Additionally, employing standardized grading criteria further ensures consistency in product quality, allowing for better market positioning and consumer trust. Washing eliminates dirt, dust, insects, mold and any residual sprays, thereby enhancing appearance and hygiene. The use of chlorinated water (100–150 ppm) or salt water (1–2%) can be used as surface contaminants. The application of disinfectants such as chlorinated water at pH 6.5–7.5 can effectively control inoculum in pack house during storage (Tapia *et al*., 2015).

Packaging of Vegetables

In India, fresh vegetables are usually packaged and transported in perforated plastic crates, gunny bags and bamboo baskets. Softer vegetables are given cushioning with dry grass, banana leaves or paper shreds, foam nets as a lining material. The consumer packages include plastic bags, and shrink wraps with or without consumer trays which is generally made up of foam or plastic (Chakraborty & Chattopadhyay, 2018). This protection can be achieved using materials like plastic films, waxed liners, etc. (Anyasi *et al*., 2016). Packaging typically falls into three categories: consumer units or pre-packaging, transport packaging, and unit load packaging or pallets (FAO, 2004). Broccoli after harvest has a limited shelf life due to high rates of respiration. Quick degradation of chlorophyll, opening of flower buds, loss of turgidity, off-flavor development and loss of nutritional quality is observed. However, shelf life of broccoli florets was increased to 49 days in flexfresh™ packaging material creating a modified atmosphere during storage at 3°C (Singh *et al*., 2018). Ethylene management is crucial to maintain quality and reduce losses (Abeles *et al*., 1992; Asrey *et al*., 2023). Different packaging materials showed varying potential for the storage of tomatoes (Singh *et al*., 2015a). Capsicum stored in 30 µ flexfresh™ expanded polyethylene biopolymer pouches increased shelf life and acceptability of capsicum (Singh *et al*., 2022). Bitter gourd fruits packed in corrugated fiberboard boxes with potassium permanganate sachets showed the lowest degradation in fruit quality compared to control during 8 days of storage at room temperature (Belwal *et al*., 2023). Singh *et al*. (2019) observed that the combined effect of different pretreatments and packaging materials were effective in maintaining quality in dried cabbage.

Edible Coating

Edible coating refers to a thin layer of edible substances applied onto surface of fresh vegetables. They reduce moisture loss and gas exchange, slow down respiration, senescence, and enzyme activity, preserve natural color, flavor, and texture and protect against microbial growth, thus retaining freshness (Mahajan *et al*., 2014). The coating on the surface of vegetables improves shelf life (Mellenthin *et al*., 1982), retains volatile flavor compounds (Nisperos-Carriedo *et al*., 1990) and carries food additives containing anti-microbial agents and anti-oxidants (Kester & Fennema, 1988). Application methods include spraying, dipping, smearing, or brushing directly onto the surface of vegetables, followed by drying to form a modified protective layer. The efficacy of these coatings depends on various factors like materials used, temperature, thickness, and vegetables. Approved edible coatings for vegetables include chitosan, cellulose, starch, gums (polysaccharides), beeswax, and protein-based coatings such as gelatin and soy proteins, all of which exhibit good barrier properties without altering taste or odor. These coatings may be combined with antioxidants, anti-microbials, nutraceuticals, and other functional compounds to enhance shelf life, quality, stability and safety. Additionally, they serve as a carrier for postharvest chemical treatments on vegetables, reducing need for synthetic packaging materials. Tomato fruit coated with gum Arabica showed prolonged shelf life, reduced weight loss, and maintained firmness and color (Ali *et al*., 2013). Similarly, cucumbers coated with edible chitosan retained firmness and quality for extended periods compared to uncoated ones in Nigeria and South Africa, respectively (Omoba & Onyekwere, 2016). Eggplant fruit coated with chitosan showed a marked extension of marketability of round shape eggplant genotypes PR-5 and BR-14 (Sharma *et al*., 2020). Sharma *et al*. (2022b) suggested that synergistic treatment of polyamines, particularly spermine 1.5 mM with chitosan (1%) was useful to extend shelf life of bell pepper by about 28 days with notable preservation of bioactive compounds. A significant increase in shelf life of shellac and carnauba wax-coated eggplant to 7 days over 3 days in control was observed during ambient storage. Carnauba wax and shellac-based edible coatings were found to enhance shelf life and retain the quality of different varieties of capsicum to 22 and 35 days, respectively over 5 to 6 days in control during storage (Singh *et al*., 2016; Singh, 2017; Singh *et al*., 2019).

Hurdle Technology

It comprises of using several hurdles together to increase shelf stability of food by inhibiting the growth of pathogenic microorganisms. The combination of several hurdles like high or low-temperature treatment, low pH, oil, sugar, salt, low water activity and preservatives at sub-optimal levels. Ozone may also be used as a disinfecting agent (Miller *et al*., 2013). It destroys microbes by damaging proteins, nucleic acids, lipids and enzymes. Ozone treatment is preferred due to its rapid and effective action, safety and zero residues, environment-friendly, rapid action and effectiveness against a broad range of microbes.

Steeping Preservation

Steeping treatment involves use of permitted additives at low levels. It is very easy to use, effective, convenient and economical technology. ICAR-IIVR has optimized the technology for the steeping preservation of cauliflower, carrot, and pointed gourd (Singh & Singh, 2015). It uses simple unit operations like blanching, use of brine solution or syrup, acetic acid, and preservatives like potassium metabisulphite or sodium benzoate. The steeped vegetables were found to be acceptable for flavor, texture, color, appearance and overall acceptability (Singh *et al*., 2015b). Sharma *et al*. (2022a) observed differences in eggplant genotypes for processing suitability. About 3.5-fold variation in browning enzymatic activity indicated scope for selecting cultivars with lesser flesh browning and thus, higher suitability for processing. 2018CAUMVAR1 cauliflower variety was found to be best in sensory acceptability (Sharma *et al*., 2022c). Cauliflower can be effectively preserved for 5 to 6 months at ambient storage temperature using low cost, easy and effective combination of sodium chloride (2–4%), acetic acid solution (1–2%) and sulfur di oxide (200–400 ppm) with hurdle concept (Singh *et al*., 2015b).

1-methylcyclopropene (1-MCP)

1-MCP functions by delaying natural ripening and aging processes in vegetables, including pigment alterations, flavor and aroma development, as well as changes in cell wall metabolism leading to softening, scalding, and browning. Acting as an antagonist to ethylene, 1-MCP binds and blocks ethylene receptors, thereby interrupting the signaling responsible for ripening. It is recognized for use in over 50 countries worldwide (Mahajan *et al*., 2014). This compound delivered either as a gas in a sealed environment or in powder form, can be applied through various methods, including gaseous treatment at room temperature, fumigation, aqueous solution dipping, or as microbubbles on vegetable surfaces, widely utilized across various vegetables like cucumbers, tomatoes and peppers (Asrey *et al*., 2023).

Value Addition

Value addition, particularly drying offers huge opportunities for vegetable preservation. Despite the potential for innovation and diversification in the vegetable sector through traditional and minimal processing techniques, many small and medium enterprises (SMEs) struggle to harness these opportunities. Challenges such as upscaling, inadequate input supplies, limited technology access, insufficient expertise, low production efficiency, high marketing costs, and compliance difficulties with international standards hinder SMEs from competing effectively in the market. Traditional processing methods in horticultural preservation can be utilized for employment generation. Processed products include preserves, sauces, pastes, concentrates, juices, fermented products like sauerkraut, confectioneries, and frozen/dried products (Rolle, 2006). Koley *et al*. (2014) observed wide variation in functional properties of different carrot genotypes indicating the need to evaluate variety's suitability for processing. Sharma *et al*. (2023) also reported that various carrot genotypes presented different probable liking, possible processing suitability and consumer acceptability which might consequently lead to different preferences for their value-added products.

Minimal Processing

Minimally processed or fresh-cut vegetables are liked due to their fresh-like characteristics, safety, and quality (Alegria *et al*., 2010; Oms-Oliu *et al*., 2010; Tapia *et al*., 2015). It offers reduced drudgery with convenience and lowers packaging and transportation costs. Texture improvers, anti-browning agents, anti-microbial agents and mild heat treatment coupled with modified atmospheric storage can be used. Cultivar selection is an important factor for quality of minimally processed products and higher shelf-life (Francisco *et al*., 2009). It is a low-cost technology with reduced energy consumption. These products are in demand due to a global change in the trend of lifestyle and purchasing power. It includes operations like cleaning, trimming, slicing, shredding, dicing, sanitizing, and packaging which vary based on specific type of produce and consumer needs (Watada *et al*., 1990; Brecht, 1995; Patrignani *et al*., 2015). These are gaining popularity due to their ability to add convenience to the consumers as well as the food business operator (FBO). However, processing for fresh-cut vegetables can cause tissue damage, hasten the growth of microbes and cause spoilage. Inadequate hygiene practices have the potential to compromise microbial quality and safety, posing potential hazards to consumer well-being (Patrignani *et al*., 2015). Unlike many other food processing methods, minimally processed fruits and vegetables become more perishable and vulnerable to both spoilage and harmful microorganisms. Therefore, their production necessitates rigorous sanitation and careful process hygiene. Consequently, maintaining a consistent cold chain becomes essential for minimally processed vegetables, requiring refrigeration at every stage, from production to consumer acquisition. Moreover, to complement refrigeration, various preservation techniques are employed, including chemical preservatives, mild heat treatment, microwave processing, ionization, high hydrolytic pressure, pulse electrical field, ozone technology, oscillating magnetic field, ohmic heating, and vacuum packaging (Siddiqui *et al*., 2011). Sodium hypochlorite and hydrogen peroxide treatment at 50 to 100 ppm for 1 to 2 minutes reduces microbial count effectively. Additionally, methods such as modified and active packaging are also used to assist in the minimal processing of vegetables (Kiaya, 2014).

Drying

It is a low-cost technique that can be employed for getting shelf-stable products. It is an effective preservation technique that can be easily used at home by solar drying or at industrial levels (James & Matemu, 2016). Low-cost drying can be done using solar driers while controlled dehydration results in better quality. USDA defined dehydrated foods as those that contain no more than 2.5% water (dry basis), whereas dried foods apply to any food product with more than 2.5% water (dry basis). It is estimated that over 20% of the perishable crops are dried to increase shelf stability (Grabowski *et al*., 2003; Sagar & Kumar, 2010). Vegetables are dried to enhance storage stability to minimize packaging costs due to bulk reduction and transportation costs. Advanced drying techniques have additional benefits over traditional drying methods like reduced time and higher drying efficiency. The drying method is selected based on cost, drying time and final product quality. Osmotic dehydration needs lesser energy and is also known as partial dehydration. It uses increased osmotic pressure due to an osmotic solution for the removal of water from the samples. The final product quality depends on factors like osmotic material, concentration, ratio of vegetable sample and osmotic material, temperature, vegetable size and shape, any other pre-treatment, etc. The main benefits of using the osmotic dehydration method are low energy consumption, low process time, higher product quality and simultaneous mass gain along with lowering of moisture content which results in effective drying and rehydration. It typically uses hypertonic solutions such as glucose, fructose, starch or salt etc. at 40 to 50°C for partial moisture removal from samples (Ahmed *et al*., 2016). Microwave drying uses electromagnetic waves in the frequency range of 300 to 300 GHz which oscillate molecules to produce heat causing quick and uniform drying. The most commonly applied frequency is 2450 MHz. It can be easily automated for large-scale drying to reduce drying time significantly. Freeze drying (FD) is an important and highly effective technology in food industry for retaining maximum quality in final dried products. This drying technique is performed at lower temperatures, restricting nutrient loss. However, it consumes large amount of energy and requires more time than conventional drying methods. Waghmare *et al*. (2023) suggested that the optimized ultrasound treatment parameters are required to improve heat and mass transfer in food samples which will help in speeding up drying and reduce drying time. Spray drying is another effective method for drying liquid to powder form. It gives high-quality products in very short time by atomization of liquid samples, by direct contact between droplets and hot air.

Drying technology has the potential to prevent enormous post-harvest losses of perishable vegetables and would help in maintaining nutritional security as well as prevent high prices of offseason vegetables (Sagar & Kumar, 2010). Osmo air-drying can be adopted on rural scale, home-scale or industry. Osmo-air drying of bitter gourd, cauliflower, carrot, okra, broccoli, cabbage, cow pea and ivy gourd slices after osmotic diffusion treatment and drying at 50 to 60°C for 6 to 8 hours has yielded high-quality shelf-stable value-added dehydrated products (Singh & Singh, 2015).

Ready-to-eat Convenience Products

Convenience foods undergo major processing by manufacturers and require very little or no secondary processing and cooking before consumption. They can be used directly for consumption after 2 to 3 minutes of heating. Demand for convenience food is growing at a fast pace due to changes in social and economic fabric and awareness about health foods. ICAR-IIVR has developed several vegetable-based convenience products. Most notable among them are bitter gourd chips which can be used as an effective technology to eliminate postharvest loss in bitter gourd, ensure off-season availability and help in the fight against diabetes. Traditionally, bottle gourd *kheer* mix is very popular in our country and is relished. However, the process for preparation of bottle gourd *kheer* mix is tedious and time-consuming. It can be stored for a short time only after preparation. Instant bottle gourd *kheer* mix developed by ICAR-IIVR can be easily reconstituted by mixing water followed by heating for 2 to 3 minutes. ICAR-IIVR Instant *Moringa* soup mix and Instant *Moringa* drink are healthy and well-liked products that can be stored for at least 6 months and can be utilized to reduce losses and ensure good nutrition. Leafy vegetables such as amaranth, spinach, fenugreek, *bathua* and *Basella* can be dried after sorting, cleaning, washing, blanching, osmotic diffusion treatment and subsequent drying to reduce final moisture to less than 2%. These dried leafy vegetables can be effectively preserved in polyethylene pouches for 6 to 8 months and can be directly used in curry preparation (Singh & Singh, 2015). Traditional method of vegetable preservation in common salt or vinegar to produce pickles is an excellent entrepreneurial opportunity due to the huge demand of pickles in our country. Pickles are not only good appetizers and taste enhancers but vegetable pickles give additional health benefits. Lactic acid bacteria can grow in acid medium and in the presence of 8 to 10% salt solution and help in giving the characteristic tangy taste and aroma of pickles.

Future Outlook

Post-harvest management and value addition in vegetables presents promising prospects for enhancing food security, economic growth, and sustainability in agriculture. Processing techniques like freezing, drying and fermentation can transform perishable vegetables into products with significantly extended shelf lives. Value addition encourages innovation and entrepreneurship. It opens doors for the creation of new products, innovative packaging solutions, and the development of healthier and more convenient food options. Small and medium enterprises (SMEs) can find new avenues for growth and employment through these ventures. Investment in research and development for improved post-harvest technologies, better infrastructure for storage and handling, and innovative processing holds key to unlocking full potential of value addition in vegetable crops. Effective upscaling of technology will contribute to economic development, and self-reliance and meet growing demands for nutritious and high-quality vegetable produce. Apart from traditional vegetable processing such as drying, canning, freezing, juice extraction and concentration etc. vegetable sector has huge potential to fuel the growth of food processing in India. Some potential future areas that require utmost importance are the nutraceutical, ready-to-eat and fresh-cut vegetable industry.

Conclusion

The current scenario highlights challenges such as significant post-harvest losses and underutilization of value-addition techniques. However, huge prospects lie in value addition, where innovative processing methods can elevate the economic value of vegetables, create diverse market opportunities, and fuel entrepreneurial ventures. These advancements not only increase the shelf life of produce but also offer consumers a wider array of nutritious and convenient food options. Realizing these prospects demands collaborative efforts, involving research advancements, technological innovations, and policy support. By harnessing these opportunities, the agricultural landscape can witness improved sustainability, reduced food scarcity, increased economic viability for farmers, and enriched consumer choices, ensuring a brighter and more sustainable future for vegetable crop management.

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सारांश

बागवानी फसलों का उत्पादन निरंतर बढ़त की ओर अग्रसर है। आज भारत, चीन के बाद सब्जियों के उत्पादन में दूसरे पायदान पर है। हालांकि, तुड़ाई उपरांत उचित प्रबंधन के अभाव में 5-15 प्रतिशत तक ताज़ी सब्जियाँ व्यर्थ हो जाती हैं। परिवहन के समय उचित तापमान और आद्र्ता की कमी से ताज़ी सब्जियों की भंडारण अवधि और कम हो जाती है। संयुक्त राष्ट्र के संधारणीय विकास लक्ष्य 2 है कि वर्ष 2030 तक तुड़ाई उपरांत क्षति को 50 प्रतिशत कम किया जा सके। तुड़ाई उपरांत क्षति, खाद्य और पोषण सुरक्षा सुनिश्चित करने में एक मुख्य वैश्विक चुनौती है। दुनिया भर में भूख, कुपोषण, अल्प पोषण और रोग को कम करने में तुड़ाई उपरांत उचित प्रबंधन की विशेष भूमिका हो सकती है। मूल्य संवर्धन की तकनीकियाँ खासकर निर्जलीकरण, विभिन्न प्रसंस्कृत उत्पादों को बनाने के लिए आधार उद्योग, फसलों के भंडारण के लिए अनुकूल तापमान और वातावरण नियंत्रण, भंडारण अवधि बढ़ाने के लिए खाद्य परतों जैसे कीटोसन, कार्बोक्सी मेथाइल सेलुलोस इत्यादि का उपयोग और सेलिसिलिक एसिड, 1-मेथाइलसाइकलोप्रोपीन, पोलिअमिन्स इत्यादि भारत और दुनिया भर के कई शोधों में सहायक पाई गई हैं। इस समीक्षा में सब्जियों की तुड़ाई उपरांत क्षति, उनके कारणों एवं उन्हें कम करने की कुछ संभावित तरीकों को प्रस्तुत किया गया है।