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A Review of Bio-Nanocoatings used to Extend Fruits Shelf Life

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Abstract

In the food business, new packaging materials are a growing sector. This interest has grown due to biopolymers' poor thermal, mechanical, chemical, and physical characteristics, as well as their intrinsic permeability to gases and vapour. Fillers that may react/interact with existing matrix to generate new formulations with enhanced qualities are required for bio polymeric materials (matrix). Many research has demonstrated that metal nanoparticles may be used to improve the qualities of bio polymeric packaging and edible coatings. The current study highlights the assessment of bio-nanocomposite films and edible coatings combined with metal nanoparticles on the shelf life and quality of tropical fruits, berries, climacteric/non-climacteric fruits and vegetables. It also includes a brief summary of some of the benefits of bio-nanocomposite films and edible coatings applied to fruits and vegetables, such as reducing colour changes, respiration rate, weight loss, and increased shelf life, delaying ripening, and being ecologically friendly. Recent publications give a better knowledge of the influence of metal nanoparticles contained in biopolymers on the shelf life and quality of fruits and vegetables.

Keywords

Bio-based polymer, Bio nanocomposite, Cut products of the soil, Postharvest-life, Normal antimicrobials, Food bundling and protection

Introduction

India is the second largest producer of fruits and vegetables in the world, next only to China. Presently, the annual production of these two commodities is estimated at approximately 197 million tonnes. Despite the remarkable progress made in increasing fruit and vegetable production in India, approximately 30-40 percent of the fresh produce goes waste. There are many reasons for this, one of which is losses occurring in the post-harvest and marketing system. Both quantitative and qualitative losses of extremely variable magnitude occur at all stages in the postharvest system from harvesting, through handling, storage, processing and marketing to final delivery to the consumer [1].

One of the major factors attributed to huge post-harvest losses in fruits and vegetables is poor shelf-life and perishable nature of these commodities. This scenario exists in most of the Third World countries and India is no exception in this regard. As a result, we are not only losing precious revenue but also compromising with the health of our vast population because fruits and vegetables are reservoirs of vital nutrients, vitamins, minerals and nutraceuticals, and are considered 'protective foods' as they protect our body from diseases. As poor shelf-life is a major culprit behind the huge post-harvest losses, extending the shelf –life for ensuring food and nutritional security assumes a great significance at present time [2, 3].

Factors influencing shelf life of fruits

The Institute of Food Science and Technology guidelines of 1993 define shelf-life as the time period during which the food product will remain safe, be certain to retain desired sensory, chemical, physical and microbiological characteristics, and comply with any label declaration of nutritional data when stored under recommended conditions. All fruits and vegetables are living plant parts containing 65 to 95 percent water, and they continue their living processes after harvest. Their post-harvest life depends on the rate at which they use up their stored food reserves and their rate of water loss. When food and water reserves are exhausted, the produce dies and decays. Anything that increases the rate of this process may make the produce inedible before it can be used [4].

Many factors affect shelf-life, ranging from pre and post-harvest environment to the genetic makeup of the concerned variety/ crop species and the physiology of harvested produce. These factors can be divided into two broad categories, viz., intrinsic and extrinsic factors. Intrinsic factors are the properties of the final produce and seem to be affected by the genetic makeup of crop and the cultural practices followed [5]. They include: water activity, pH value and total acidity, redox potential, available oxygen, nutrients, natural microflora and surviving microbial counts. Extrinsic factors, on the other hand, are those which the final produce encounters as it moves through the food chain [6]. They include the factors like temperature, relative humidity and light control during processing, storage and distribution, composition of atmosphere within packaging and consumer handling [7]. All these factors can operate in an interactive and often unpredictable way and the probability of interaction must be investigated as shown in figure 1.

In the context of increasing concern of the environmental damage due to synthetic plastic packaging and consumers' awareness on harmful effects of synthetic inputs in our food, biopolymer based nanocomposites offer attractive alternatives. Recently, concerted efforts to protect the environment not only by using natural renewable materials environmentally friendly, but also using materials that decompose naturally in the environment was done and increasing rapidly (Figure 2). One of these materials is biopolymers, a kind of polymers, that produced by living organisms such as alginate and carrageenan which produced naturally occurring anionic polysaccharide isolated from the seaweeds (Figure 2) [1], Mycocel found in plant cellulose and fugi fibers [8], carboxymethyl from bacterial cellulose and asparagus stalk [9, 10], cutin from *S. Myriacanthum* and *S. Aculeatissimum* [11], lignocellulosic from *I. paraguariensis* [12], gelatin and cactus mucilage from *P. volubilis* [13], chitosan found in insects and crustacean's shells of certain other organisms, including many fungi, algae, and yeast [2]. Monomeric units of biopolymers are sugars, amino acids, and nucleotides. Cellulose, starch and chitin, proteins and peptides, DNA and RNA are all examples of biopolymers.

Biopolymer matrices can be effective carriers of active ingredients such as post-harvest decay control [14], antimicrobial activity [15], UV light barrier [16], antioxidant activity [17, 18], anti-browning [19], storage stability [20], controls the spoilage related microflora in fruits [21], inactivation of foodborne bacteria [22], shelf life extension [23], dehydrating agent [24], cytotoxicity [25], water vapour barrier efficiency [26], deacetylation degree for fruit preservation [27], ascorbate retention [28], antifungal agent [29], preserves the quality of fresh cut fruits [30], production of off-flavours in fruits [31], natural colour protectant in fruits [32] and biocontrol for yeast growth in fruits [33].

Applications of bionanocoatings derived from plants and animals

Coating process involves many steps; formulation of raw materials using suitable proportion of biopolymers and active agents or nanomaterials such as chitosan coating on storage stability of tomatoes [34], quinoa protein/chitosan edible films; antifungal effect in cherry tomatoes [35], chitosan-based colloid incorporating grapefruit seed extract for cherry tomato [36], Tyrosol-enriched tomatoes by diffusion across the fruit peel from a chitosan coating [37], chitosan-zein coating containing free and nano-encapsulated coatings for *Pulicaria gnaphalodes* [38], *Aloe Vera* gel as coating agent for stored Pomegranate seeds [39], alginate and chitosan add ZnO nanoparticles applied in guavas for antimicrobial coatings [40], bionanocomposite film based on whey protein biopolymer loaded with TiO_2 nanoparticles, cellulose nanofibers and rosemary essential oil for increasing the shelf life of fruits [41], biopolymer-chelated fabrication of cobalt nanoparticles encapsulated in N-enriched graphene shells for biofuel upgrade [42], zinc oxide nanocomposites coating for fruits preservation [43], salicylic acid blending in chitosan/PVP biopolymer coating used as antioxidant enzyme for low storage temperature stress of 'Banati'guava fruit [44], alginate-and gellan-based edible films for probiotic coatings on fresh-cut fruits [45], WPI dip coatings for applications on fresh whole and cut fruit [46], alginate-glycerol-citric acid biofilm coating over the papaya puree to retain the freshness [47], essential oils encapsulated used as antimicrobials in fruits [48], gum Arabic, xanthan and carrageenan coatings used as antimicrobial agent on postharvest quality of fruits [49], Guar gum coatings used to increase the shelf life of Pitaya [50], A. vera gel used as edible coatings on mango fruit ripening and ripe fruit quality parameters including color, firmness, soluble solids concentrations, total acidity, ascorbic acid, total carotenoids, fatty acids, and aroma volatiles [51] and use of almond gum and gum Arabic coating to delay postharvest ripening of fruits [52].

Nanospray coatings

The use of nano spray drying for nanoencapsulation of bioactive food ingredients is still at an early stage, but is constantly evolving [53]. The feasibility of encapsulating bioactive food ingredients in submicron particles by nano spray drying has been demonstrated in various studies are as follows:

Factors affecting shelf life of fruits

Pre-harvesting

Related to plants

1. Type of fruit pulp
2. Cultivators
3. Planting density

Related to inter cultural operation

1. Water relation and migration
2. Mineral nutrition
3. Nitrogen phosphorus, potassium, zinc and calcium content

Canopy manipulation

1. Fruit thinning
2. Fruit position in the tree
3. Girdling

Use of agro chemicals

1. BA, IAA, GA3
2. B-9 & CCC- Growth retardants

Related to environment

1. Light (High light intensity (3000-8000 F.C)
   Absorption of red light (625 – 700nm)
2. Humidity
3. Temperature
4. Rainfall

During harvest factors

1. Season
2. Time
3. Method of harvesting
3. Stage of harvesting

Pest and diseases

1. Fungi
2. Bacteria
3. Mites
3. Insects

Post-harvesting

1. Pre- cooling
2. Washing and drying

Sorting an grading

Basis of size, colour, range of damage and ripening stage

3. Packaging and packaging materials
4. Storage

Transportation

Mechanical damage of fruits are caused by careless handling during harvesting, packaging, transportation and storage.

Microbial action

Fungi, bacteria, yeast and moulds

Environmental factors

1. Temperature
2. Humidity
3. Composition and proportion of gases in controlled atmospheric storage

Secondary causes

Inadequate methods in harvesting, transportation, storage and Marketing facilities and legalization results in favorable conditions for the secondary causes.

5. Harvesting and field handling
6. Reducing moisture loss
7. Marketing of fresh produce

Storage at low temperature

Primary purpose to control rate of respiration, transpiration, ripening, undesirable biochemical changes and disease infection.

Figure 1: Factors affecting quality and shelf life of fruit crop.

Microencapsulation of food ingredients [53, 54], controlling the weight loss of fresh produce during postharvest storage under a nano-size mist environment [55], knockdown of fruit flies by imidacloprid nanoaerosol [56], Lactoferrin-based nanoemulsions to improve the physical and chemical stability of omega-3 fatty acids [57], increases the freshness of the fruit [58], preserving the strength of corrugated cardboard under high humidity condition using nano-sized mists [59], biological control of yeast [60], improves the colour appearance in fruits [61], increase the quality and yield of fruit crop [62], eegulates nitric oxide production in peach fruit during cold storage [63], production of carotenoid-based colorants with enhanced bioavailability [64] and relives the oxidative stress in plants [65].

Sonochemical chemical coatings with nanoparticles

Sonochemistry is the application of ultrasound to chemical reactions and processes. The mechanism causing sonochemical effects in liquids is the phenomenon of acoustic cavitation. Hielscher ultrasonic laboratory and industrial devices are used in a wide range of sonochemical processes. Ultrasonic cavitation intensifies and speeds up chemical reactions such as synthesis and catalysis [66]. This kind of highly advanced techniques used in agricultural sectors with the various types of nanoparticles reinforcement such as nanocomposite Zinc Oxide-Chitosan coatings on Polyethylene films for extending storage life of Okra [67], pectin, pullulan, and chitosan increase quality and shelf life of strawberries [68], antimicrobial activity [69], Methylcellulose-based edible coating on strawberry fruit's quality maintenance during storage [70], chitosan-

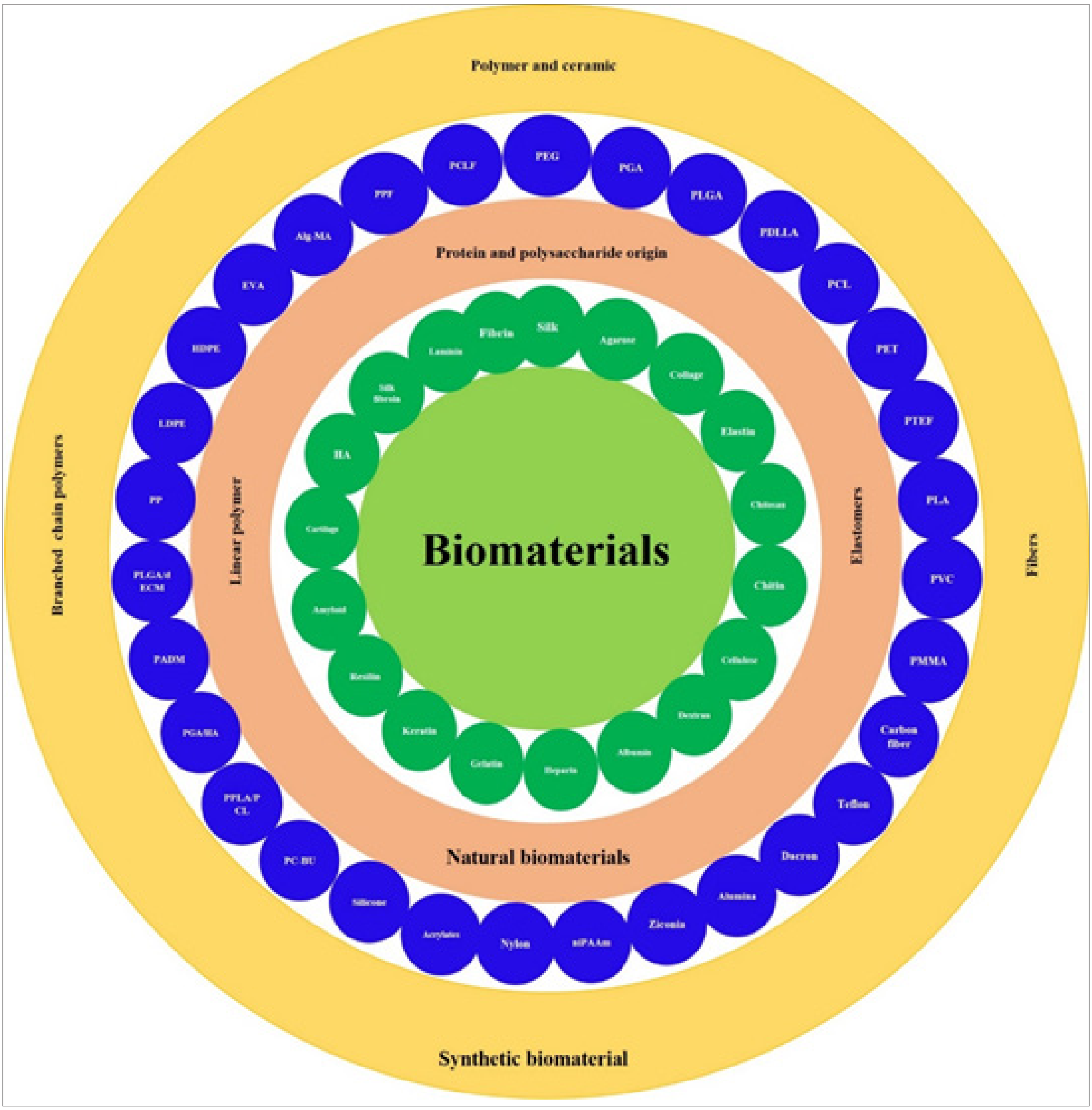

Figure 2: Sources of biomaterials.

tripolyphosphate nanoparticles suspension as an antibacterial agent [71], inactivation of food pathogenic microbes [72], Pre-storage application of calcium chloride to improve the shelf life of straw berry [73], ascorbate retention and degradation during the washing and post-harvest storage of spinach and other salad leaves [74], controlled atmosphere storage of fruits and vegetables [75], pre storage treatment with 6-benzylaminopurine and modified atmosphere packaging storage on the respiration and quality of green asparagus spears [76] and combined effects of aqueous chlorine dioxide and ultrasonic treatments on postharvest storage quality of plum fruit [77]. In addition, by compiling recent knowledge, advantages of coatings on fruits for nutritional security during COVID-19 pandemic are also summarized along with the scientific challenges and insights for future developments in fabrication of engineered nanocoatings.

Conclusion

Biopolymers derived from plants such as starch, cellulose, agar, carnauba; those derived from animals such as gelatin, casein, whey protein, beeswax; and those derived from microorganisms such as dextrans, xanthan, pullulan, bacterial cellulose and polylactic acids have been extensively studied and applied as biodegradable alternatives to synthetic plastic packaging. Solution casting method is most commonly used to develop these films including their blends or hybrids. Numerous studies have reported that reinforcement of these biopolymers with nanomaterials such as CNF, nano-MMT, ZnONPs, AgNPs not only effectively improved physico-chemcal, mechanical, barrier properties, but also enriched them with functionalities such as antimicrobial and antioxidant activities. The biopolymer based nanocomposites have been applied to package fresh produce, and studies have shown postharvest-life ranging from 4 days to 2 months depending on types of whole fruits and vegetables and storage conditions. Applications of the nanocomposite coatings on cut fruits reported shelf-life of 14 to 40 days depending on type of fruits. Further research is needed on scale-up and commercialization of the biopolymer based nanocomposite films and coatings, so that they are affordable and easily applicable to produce growers or handlers.

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