Chapter 1 Introduction

Biopolymers are polymers produced from biological sources that are generally renewable in nature, such as proteins and polysaccharides from plants, animals and microorganisms. These biopolymers are receiving greater attention as alternatives to synthetic polymers for several technological applications and processes mainly due to their biodegradability and safety. Among the available biopolymers, Aloe vera gel and chitosan biopolymers have a long history of usage and numerous health benefits.

History of use and production

Aloe barbadensis Miller, popularly known as Aloe vera, is an herbaceous, shrubby, perennial, xerophytic succulent, belonging to family Liliaceae. Aloe vera is known in India as Ghrit Kumari, Kunvar Pathu and India Aloe. This ‘miracle plant’ has been used in folk medicine for over 2000 years in China, India, West Indies and Japan. It enjoys a major market presence across the globe and is commercially cultivated in the United States, Japan, India, as well as in some Caribbean and Mediterranean countries. Production in India is mainly in the states of Maharashtra, Andhra Pradesh and Tamil Nadu (Chauhan et al., 2007).

Aloe vera leaves are processed basically into two products, inner gel and the latex. Aloe gel is the transparent, slippery mucilage produced by the thin-walled tubular cells found in the leaf parenchyma (Hamman, 2008). The polysaccharides present in the Aloe gel, especially, the partially acetylated glucomannans is considered the active principle.

Chitosan is a biodegradable polymer made commercially by alkaline deacetylation of chitin, obtained from cell walls of some fungi and from shells of crustaceans as a marine food industry waste. It is a bioactive polysaccharide composed of N-acetyl D-glucosamine units (Synowiecki and Al-Khateeb, 2003). Japan and United States are the main producers of chitosan followed by India, Italy and Poland (Dutta et al., 2004).
The biopolymer properties and studies related to the present investigation are reviewed below briefly:

**Antimicrobial activity and edible coating applications**

The antimicrobial activity of *Aloe vera* gel has been reported using *in vitro* (Saks and Barkai-Golan, 1995; Jasso de Rodriguez *et al.*, 2005) and *in vivo* inoculation studies on fruits against plant pathogenic fungi (Abirami, 2009; Navarro *et al.*, 2011). Several phytochemicals present in *Aloe vera* gel such as saponins, alkaloids, tannins, glycosides, flavonoids and terpenoids are known to be responsible for its antimicrobial activity (Arunkumar and Muthuselvam, 2009). Chitosan is known to be inherently anti-microbial. Its anti-fungal action has been proved in both *in vitro* and *in vivo* assays (El Ghaouth *et al.*, 1992; Romanazzi *et al.*, 2002; Devlieghere *et al.*, 2004).

The postharvest applications of biopolymers include their use as edible coating for improving the shelf life and quality of fruits and vegetables. The coatings act as a gas barrier and delay ripening. Due to their natural antimicrobial properties, *Aloe vera* gel and chitosan biopolymers also act as biopreservative coatings and prevent microbial decay.

Aloe gel has been recently explored as an edible coating in tropical fruits such as papaya (Marpudi *et al.*, 2011) and in temperate fruits such as table grapes (Valverde *et al.*, 2005) and sweet cherries (Serrano *et al.*, 2006) with promising results.

Chitosan coating has been reported to extend shelf life in tomatoes, bell peppers, cucumbers, strawberries, lettuce and peaches (El Ghaouth *et al.*, 1992; Devlieghere *et al.*, 2004). The polymer has also been found to reduce decay in fruits such as table grapes, mangoes, sweet cherries, papaya, oranges and carrots (Donglin and Quantick, 1998, Romanazzi *et al.*, 2002).

Apart from whole fresh agricultural produce, demand for minimally processed fruits and vegetables (MPFV) has increased tremendously in the past few decades. However, the highly perishable nature of MPFV creates a major challenge to preserve their freshness and safety. Disadvantages associated with current preservation methods
combined with consumer preference for natural additives have necessitated the search for safer alternatives. Hence, this is another potential area of postharvest application of the antimicrobial natural polymers. Effect of chitosan solution coating on MPFV have been investigated and include peeled litchi, sliced red pitayas and fresh cut broccoli (Dong et al., 2004; Chien et al., 2007). But, there is still a good scope to further explore its application in this area. With regard to Aloe gel biopolymer, however, there is paucity of studies on its preservative role in minimally processed produce.

_Nutritional and nutraceutical properties_

_Aloe vera_ is a mixture of a wide variety of biologically active components. These substances which are naturally present are known to have synergistic effect and also counteract side effects. These include vitamins, minerals, enzymes, sugars, anthraquinones or phenolic compounds, lignins, saponins, sterols, amino acids and salicyclic acid (Hamman, 2008). _Aloe vera_ gel has also been shown to enhance bioavailability of vitamin C, vitamin E and B₁₂ in clinical trials (Vinson et al., 2005; Yun et al., 2010).

_Aloe vera_ has been shown to possess anti-diabetic, immunomodulatory, anti-oxidant, wound healing, anti-cancer and hepatoprotective activities. It has been promoted for the treatment of constipation and other gastro-intestinal disorders. _Aloe vera_ is also reported to possess significant anti-bacterial, anti-viral and anti-fungal activities (Boudreau and Beland, 2006; Hamman, 2008).

_Aloe vera_ gel has been shown to significantly increase the transport of insulin in a Caco-2 cell model (Chen et al., 2009). Oral use of the gel has been reported to lower blood glucose levels in type 2 diabetes mellitus, reduce associated cardiovascular complications, stabilize metastatic cancer, and cure ulcerative colitis (Benzie et al., 2011).

Chitosan is classified as a dietary fiber as per the definition given by Codex Alimentarius Commission in 2009. Chitosan nanoparticles have been also found to increase gastric emptying due to its action as a dietary fiber (Zhao et al., 2011). It is also a good source of minerals.
Chitosan has been reported to exhibit hypoglycemic, hypolipidemic (Yao, 2008), and anti-oxidant activity (Kim & Thomas, 2007). Other biological activities reported include antimicrobial, immune stimulating, anti-inflammatory and anticancer effects. It is also reported to accelerate calcium and iron absorption, and inhibit Angiotensin-I-converting enzyme (ACE) activities (Xia et al., 2011).

**Functional food applications**

Addition of the selected biopolymers to foods is expected to improve the nutritional as well as the nutraceutical profile of foods. Hence, they have both health and economic potential to be promising components of functional foods.

Aloe gel is considered as a safe functional ingredient in foods (Eshun and He, 2004; Rodríguez et al., 2010). Aloe gel has also been utilized in the development of health food drinks and other beverages, candies, chewing gum, jams, jellies, sorbets, concentrates, yoghurts, ice-creams and other milk products (Chauhan et al., 2007). However, only very few of these products have reached the market. Further, scientific information on the therapeutic effects of such products is lacking. The FDA refers to Aloe vera as food, herb or a dietary supplement (Yogeeswaran et al., 2005).

Chitosan has been explored as an additive in fruit juices, eggs, dairy, cereal, meat and sea food products, and cheese (Kerch et al., 2010; Friedman and Juneja, 2010). The Japanese Ministry of Agriculture, Fisheries and Foods have approved several products (eg: biscuits, fishcakes) containing chitosan as “Food –for Specified Health Use” (FOSHU) (Prashanth, 2010). Nissin group, Japan, is marketing noodles with chitosan as a health food (www.nissinfoods.co.jp). The wide food applications of chitosan has led to the possibility of its addition to the generally recognized as safe (GRAS) list in the United States (U.S. Food and Drug Administration, 2005).

The potential use of this polysaccharide has not yet been explored in Indian wheat based foods. Wheat and wheat based traditional foods can serve as ideal vehicles for the development of functional foods. This could improve the health of millions of consumers through the wide variety of products prepared from wheat.
It is clear that these bioactive biopolymers offer a great potential for their utilization. Fresh ventures using these unique polymers are expected to be successful and useful for both indigenous use and for export. In view of the projected beneficial effects of the biopolymers and the increasing emphasis on eco-friendly natural products, the present investigation aims to study the applications of Aloe vera gel and chitosan biopolymers in the areas of edible coating technology, functional food processing and nutraceutical applications.

**Societal relevance of the research**

*Food and Environmental concern:* The study explored edible coating utilizing Aloe vera and chitosan as simple environmental friendly postharvest technology for reducing post-harvest losses in fruits and vegetables.

*Health concern:* Demand for natural antimicrobials for replacing chemical preservatives in processed foods has been increasing in view of its health implications. Effective use of these biopolymers as bio preservatives in fresh cut produce and as natural food additive in functional foods would be beneficial. Elucidation of the nutraceutical potential of Aloe gel and chitosan as part of food formulations could result in their use as natural alternative therapy for oxidative stress related disorders and diabetes.

*Social concern:* Expanding the utilization of these biopolymers in food and health applications would help to further strengthen the eco-viable enterprises related to Aloe vera and chitosan processing which could also provide employment to rural and urban poor.

The **objectives of the study** set forth include:

1. **Edible coating applications**
   
   1.1 To evaluate the efficacy of Aloe gel and chitosan biopolymer coatings for extending shelf life and quality maintenance of whole fruits
   
   1.2 To study the effect of powder coating using Aloe gel and chitosan biopolymers on bioactive compounds and shelf life quality of fresh cut vegetables
2. Functional food processing applications

2.1 To develop fruit and dairy based products incorporating Aloe gel and evaluate their quality characteristics

2.2 To study the impact of chitosan enrichment on functional and nutritional properties of wheat flour and wheat flour based product (chapati)

3. Nutraceutical applications

3.1 To analyze the nutraceutical potential of formulated Aloe gel and chitosan enriched products

3.2 To determine the short term glycemic response of select developed Aloe gel and chitosan enriched products in normal and diabetic subjects

These objectives will be covered in the following chapters:

Chapter 1 Introduction

Chapter 2 Nutritional, phytochemical and nutraceutical characterization of Aloe gel and chitosan biopolymers

Chapter 3 Efficacy of Aloe gel and chitosan biopolymer coating on postharvest quality and shelf life of whole fruits

Chapter 4 Efficacy of Aloe gel and chitosan biopolymer powder coating on quality and shelf life of minimally processed vegetables

Chapter 5 Formulation and quality evaluation of Aloe vera gel enriched functional foods

Chapter 6 Formulation and quality evaluation of chitosan enriched functional foods

Chapter 7 In vitro nutraceutical (antioxidant and antidiabetic) potential of Aloe gel and chitosan enriched functional food products

Chapter 8 Evaluation of post prandial glycemic response of Aloe gel enriched dahi and chitosan enriched chapati in normal and diabetic subjects

Chapter 9 Summary and conclusions