Starch Based Packaging Materials: A Review

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ABSTRACT *Mainly due to environmental problems, petroleum-based plastics are being replaced by natural polymers. In the last decades, starch has been evaluated for its film-forming ability for application in the food packaging area. Characteristics of the starch film matrices, the film formation methods, and physico-chemical properties of the starch films are reviewed in this below paper. The effects of different components added in casting methods and thermoplastic processes have been also analyzed. Physicochemical properties of the starch films showed a great variability depending on the compounds added to the matrix and the processing method. Dry methods (extrusion) are more recommendable for film manufacturing because of the greater feasibility of the industrial process.*

Keywords: *Starch Films, Plastics, Physicochemical Properties, Dry Methods.*

1. Plastics As Packaging Material

Plastics derived from petroleum are the most common packaging materials in the food industry. Plastics degradation takes long time and can cause many environmental problems by not being biodegradable **(Sorrentino *et al.* 2007; Xu *et al.* 2005).** World production of plastics materials has demonstrated a continuous growth for more than 50 years. It is currently estimated that the production of these materials rose to 300 million tons **(Plastics Europe, 2015).** Packaging applications represent around 39.6% of the total plastics demand and is considered the largest
market for the plastics industry. The production and consumption of plastics have increased in geometrical progression. The annual per capita consumption of plastics in India is 2 kg/person/year compared to 60 kg/person/year in developed countries. In India, plastics wastes accounts to 3% by weight of total of 80,000 metric tons of municipal solid waste generated daily **(Kalia *et al.* 2000).**

2. Biodegradable Material as Packaging Materials

A biodegradable film could be defined as a primary packaging made from biodegradable polymers and food-grade additives. A thin layer of biodegradable material can be formed into a film and might be used as a food wrap without changing the original ingredients or the processing method. Biodegradable films have been used for protection and to extend the shelf life of several food products **(Galus *et al.* 2015)**. Also, biodegradable films can reduce environmental problems associated with food packaging. The concept of biodegradability enjoys both user-friendly and eco-friendly advantages. An additional advantage of these packaging materials is that on disintegration they may act as fertilizer or soil conditioner, enhancing crops yield. Though somewhat expensive, bio-plastics are tomorrow's need for packaging. Currently, the applications of biodegradable polymers in the food industry include disposable cutlery, drinking cups, lids, plates, overwrap and lamination films, straws, stirrers, containers for food dispensed at gourmet food stores and fast-food establishments **(Siracusa *et al.* 2008).** In addition, some biodegradable films may also be edible and be consumed with the food they are wrapping. Many studies show evidence of the beneficial effects of using such films on fresh and processed foods **(Chillo *et al.* 2008).** Biodegradable packaging made from entirely renewable natural polymers can decrease environmental pollution, as they degrade after their disposal, creating new markets for agricultural products **(Xu *et al.* 2005).** The applications of polysaccharide based films in food products could offer new opportunities to develop novel food packaging systems. Starch is a natural polymer that could be an alternative to produce food packaging materials. It has been extensively studied because it is abundant, cheap, biodegradable and edible.

3. Starch as Packaging Materials

Starch is an agricultural polymer found in a variety of plants including wheat, corn, rice, beans, and potatoes **(Kolybaba *et al.* 2006).** This polymer constitutes more than 60% of cereal kernels and it is relatively easy to separate from the other components **(Jimenez *et al.* 2012*).*** Depending on the botanical source, starch granules vary in shape, size, structure, and chemical composition (**Molavi *et al*. 2015).** The starch granules are essentially composed of two main polysaccharides: amylose and amylopectin. Starch granules contain also trace amounts of other components such as lipids and proteins. Amylose is a linear chain polymer of α-1, 4 anhydroglucose units with a molecular size ranging from 200 to 800 kg/mol. It accounts for about 20-25% of most granular starches. The amylase is responsible for the film-forming properties of the starch **(Bertuzzi *et al.* 2007b).** Amylopectin is a highly branched polymer of short α-1, 4 chains linked by alpha-1, 6 glycosidic branching points occurring every 25-30 glucose units and with a very high molecular weight (5000-30,000 kg/mol) (**Peressini *et al.* 2003).** When a hot gelatinous starch melt is cooled, the dispersed amylase molecules re-associate in a process known as retrogradation and form elastic gels. Starch gels consist of a three-dimensional matrix of a continuous phase of amylose molecules containing uniformly dispersed ghosts that act as filler (Morris, 1990). The heterogeneous nature of starch pastes may not be a concern in many food and industrial applications and can, in fact, even be beneficial. Starch granules are insoluble in cold water as the hydrogen bonds hold the starch chains together. However, when starch is heated in water, the crystalline structure is disrupted and water molecules interact with the hydroxyl groups of amylose and amylopectin resulting in a partial solubilisation. To obtain a homogeneous film forming solution of starch, it is necessary to gelatinize the granules in an excess of water (>90% wt. / wt.). This process breaks the amylopectin matrix and releases the amylose. To obtain films from starch, two techniques are mainly employed: wet process which is also known as casting and dry process.

4. Different Sources of Starch and Their properties

Biological source

Starch consists of polysaccharide granules obtained from the grains of Maize Zea mays L. or of rice Oryza sativa L or of wheat Triticum aestivum L. (Family- Graminae) or from the tubers of the potato Solarium tuberosum L. (family- Solanaceae).

Geographical source

Starch is commercially produced in tropical and subtropical countries. Argentina, U.S.A, China, India and Japan are the main starch producing countries of the world.

Macroscopical characters

Starch is found in irregular, angular masses or in form of white powder, it is insoluble in cold water and forms a colloidal solution on boiling. After cooling, the starch solution becomes translucent jelly.

Microscopy of Some Starch

The germs are continuously separated from suspension by liquid cyclones (hydrocyclones) and it is used in the preparation of germ oils. The germs oil is rich in vitamins and possesses unsaturated fatty acid like linolenic and linoleic acids.

The starchy milky liquid contains some proteins, which are separated by the use of special starch purification centrifuges.

Chemical Constituents:

(i) Starch contains generally a mixture of two polysaccharides, amylopectin (α- amylose) and amylose (β-amylose).

(ii) Amylopectin it is the main constituent of most of the starches (more than 80%) and is present in outer parts of granules. It contains both strait chained and branched glucose unit. It is insoluble in water and is responsible for gelatinizing property. It gives bluish black colour with iodine solution.

(iii) Amylose most starches contain 20% amylose. It contains straight chained glucose units and is present in inner parts of granules. It is soluble in water and produces blue colour with iodine solution.

5. Role of Plasticizer

In most of the cases, the addition of plasticizers is required in order to obtain protein and polysaccharides-based films. When no plasticizer is added, the films obtained from several polysaccharides are brittle usually due to interactions between polymer chains **(Han 2014).** Plasticizers reduce cohesion within the film network by weakening the intermolecular forces between adjacent polymer chains **(Espitia *et al.* 2014).** In this way, plasticizers modify or improve the mechanical properties, reduce the tension of deformation, hardness, density and viscosity and increase the polymer chain flexibility as well as the resistance to fracture **(Vieira *et al.* 2011).**

6. Advantages of Starch Films

1. Comes from plant sources, which is a renewable resource
2. Does not contain toxins
3. Producing this kind of plastic creates much less greenhouse gas emissions than conventional plastic production (a reduction of 68 percent)
4. Starch plastic can be composted in facilities for industrial composting

5.65 percent less energy is needed to produce corn-based plastic than to produce conventional plastic

7. Conclusion and Future Prospects

With an ever-increasing world population, the question is not whether the global environment will be impacted by our presence but how and to what degree. To that end, there is a need to perpetuate the culture of environmental stewardship and sustainability that has grown stronger in recent years. Consumers and municipalities must continue to demand more sustainable packaging materials and practices. Retailers must continue to provide suppliers incentives for greater sustainability in their packaging choices. Although some of the starch-based materials and other biopolymers may not currently be cost-competitive with petroleum plastics, this may change as petroleum prices increase. Starch is poised to establish an even stronger role in the manufacture of sustainable plastics and other bioproducts largely because it is abundant, renewable, and inexpensive. The cost and availability of starch may improve even further in the future. Strategies for improving the properties of starch-based plastics such as blending starch with other polymers, using starch in composite materials, and using starch as a fermentation feedstock to make other biopolymers have been successful in developing viable replacements for petroleum- based plastics. The prospects for starch in the packaging sector continue to become brighter as the market for sustainable plastics drives further innovation and development.

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