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Use and application of gelatin as potential biodegradable packaging materials for food products

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ABSTRACT

The manufacture and potential application of biodegradable films for food application has gained increased interest as alternatives to conventional food packaging polymers due to the sustainable nature associated with their availability, broad and abundant source range, compostability, environmentally-friendly image, compatibility with foodstuffs and food application, etc. Gelatin is one such material and is a unique and popularly used hydrocolloid by the food industry today due to its inherent characteristics, thereby potentially offering a wide range of further and unique industrial applications. Gelatin from different sources have different physical and chemical properties as they contain different amino acid contents which are responsible for the varying characteristics observed upon utilization in food systems and when being utilized more specifically, in the manufacture of films. Packaging films can be successfully produced from all gelatin sources and the behaviour and characteristics of gelatin-based films can be altered through the incorporation of other food ingredients to produce composite films possessing enhanced physical and mechanical properties. This review will present the current situation with respect to gelatin usage as a packaging source material and the challenges that remain in order to move the manufacture of gelatin-based films nearer to commercial reality.

1. Introduction

Petrochemical-based plastics such as polystyrene (PS), polyamides (PA), polyethylene terephthalate (PET) polyethylene (PE), etc. are widely used for food packaging applications, frequently as part of laminated constructions, due to their excellent structural properties, performances, gas or water barrier properties, aesthetic qualities and cost. However, an ever growing negative attribute associated with these materials is that they are not deemed to be environmentally-friendly as they are not; considered to be derived from sustainable sources (much of the connventionally used plastic-based packaging is derived from the gaseous by-products of crude oil processing; crude oil being a finite resource), recyclable, compostable or biodegradable. Consequently, much of the conventional packaging materials used for food application today, by its very nature, must controversially be sent to landfill for dumping or to recovery sites for incineration. Either way, environmental impact is a real issue and in its most negative form has implications with regard to public health.

Biodegradable and/or edible films have the potential to reduce, or in some circumstances, completely replace some traditional polymeric packaging materials for specific applications. However, in order to do so, bio-based packaging must perform like conventional packaging and provide all of the necessary functions of containment, protection, preservation, information, convenience in a legally and environmentally-compliant manner, cost-effectively.

Biodegradable packaging materials are naturally comprised of polymers that should be capable of being ultimately degraded by microorganisms (bacteria, fungi and algae) through composting processes to produce natural breakdown compounds such as carbon dioxide, water, methane and biomass. There are two types of biodegradable polymers; those which are non-edible or edible. Biodegradable materials derived from food ingredients such as polysaccharides, proteins and lipids are edible and have attracted considerable interest in recent years due to their potential abilities to replace traditional plastics and act as food contact edible films and/or coatings. Examples of biopolymers (including food ingredients) that have potential usage in the manufacture of packaging materials for food applications are shown in Fig. 1.

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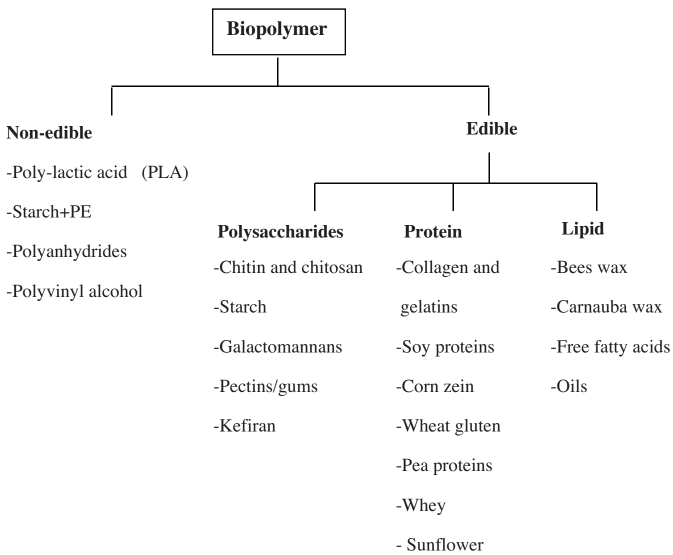

Fig. 1. Biopolymer usage for the potential manufacture of biodegradable packaging films.

2. Edible and biodegradable films and coatings

An edible/biodegradable film is one which is typically produced from food-derived ingredients in a thin layer using wet or dry manufacturing processes to do so. The resulting film should be a free-standing sheet used over the food as wrapping or could be used between food components for separation. In contrast, edible coatings are materials which can be applied directly to the surfaces of food products by dipping, spraying or panning. Edible packaging formats can be consumed with, or as part of, the food product in question, but they may fulfill other functions; like acting as carriers for targetted food additives (antimicrobial agents, antioxidants, flavourings, etc.). Edible films and coatings may also be used to inhibit migration of moisture, oxygen, carbon dioxide and/or to improve the mechanical integrity or handling characteristics of the food [1].

Prior to the application of these biopolymers, some factors need to be considered such as microbiological stability, solubility, transparency, wettability, oil and grease resistance, cohesion, mechanical properties, sensory and permeability to water vapour and gases. Preparation of biodegradable and/or edible films involves the use of at least one film-forming agent (macromolecule); polysaccharides, proteins and/or lipids, a solvent and a plasticizer. Hydrocolloids (proteins and polysaccharides) are the most widely investigated biopolymers in the field of edible coatings and edible films [2].

A plasticizer is a molecule of low volatility and is added to polymeric materials to; modify their three-dimensional organization, decrease attractive intermolecular forces and increase free volume and chain mobility [3]. The changes in molecular organization allow plasticizers to modify the functional properties of films by increasing extensibility, dispensability, flexibility, elasticity, mechanical properties and rigidity [3]. Plasticizers such as glycerol, sorbitol and glycol are essential to make the films more flexible, softer and avoid pores and cracks in the polymeric matrix. However, addition of plasticizers can significantly change the properties of films, including; decreasing tensile strength (TS), increasing film permeability to water and increasing the capacity of the films to adsorb water [4–6]. In this respect, the type and quantity of plasticizers used and their function in the films contribute significant attributes to the ultimate performances of the films.

Table 1
Amino acids listing and basic properties.

Amino acid name	Abbreviation[a]	Properties
Alanine	ala (A)	Hydrophobic (Nonpolar)
Arginine	arg I	Positively charged
Asparagine	asn (N)	Hydrophilic (Polar)
Aspartic acid	asp (D)	Negatively charged
Cysteine	cys I	Hydrophilic
Glutamic acid	glu (E)	Negatively charged
Glutamine	gln (Q)	Hydrophilic
Glycine	gly (G)	Hydrophobic
Histidine	his (H)	Positively charged
Isoleucine	ile (I)	Hydrophobic
Leucine	leu (L)	Hydrophobic
Lysine	Lys (K)	Positively charged
Methionine	met (M)	Hydrophobic
Phenyl-alanine	phe (F)	Hydrophobic
Proline	pro (P)	Hydrophobic
Serine	ser (S)	Hydrophilic
Threonine	thr (T)	Hydrophilic
Tryptophan	trp (W)	Hydrophobic
Tyrosine	tyr (Y)	Hydrophilic
Valine	Val (V)	Hydrophobic

[a] Abbreviation for three and single letter code.

3. Proteins

Proteins are polymers containing more than 100 amino acid residues and made from 20 proteinogenic amino acids that are joined together by amide bonds called polypeptides. Proteins are very different in form and function depending on their origin, structures and amino acid composition (Table 1). Each amino acid composition is comprised of a central carbon (α carbon) bonded to hydrogen, a carboxyl group (COOH), an amino group (NH_2) and a unique amino acid side chain or R group, which identifies and distinguishes one amino acid from another.

Proteins are classified into four basic structures, namely; primary, secondary, tertiary and quaternary forms. A primary protein structure is one where the amino acid sequence is arranged linearly. Meanwhile, a secondary protein structure is one where the shape of the protein molecules exist in either α helix or β sheet (folding and coiling) and which is brought about by hydrogen-bonding between –C=O and –N–H groups within the chain and the primary amino acid building blocks. The tertiary protein structure results when folding and bending of the protein molecules occurs due to interactions with the R groups on individual amino acids. This interaction may occur as a result of hydrogen bonding, dipole–dipole interactions, covalent bonding or ionic bonding (salt bridges) depending on the polarity of the R groups. Meanwhile, a quaternary protein structure results as a consequence of non-covalent interactions that bind multiple polypeptides into a large macromolecular complex.

3.1. Protein-based edible/biodegradable films

Generally, proteins must be denaturated by heat, acid, alkali, and/or solvent in order to form the more extended structures which are required for film formation [7]. The films obtained consist of chain-to-chain interactions (hydrogen, ionic, hydrophobic and covalent bonding) that produce cohesive films but the interaction is affected by the degree of chain extension and the nature and sequence of amino acid residues [7]. Compared with synthetic films, protein-based films exhibit poor water resistance and lower mechanical strength. Yet, proteins are still generally superior to polysaccharides in their ability to form films with greater mechanical and barrier properties [8]. Protein-based films possess better oxygen and carbon dioxide barrier properties and mechanical properties than polysaccharide films.