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Edible films from Polysaccharides

Aruna Dhanapal, Sasikala.P, Lavanya Rajamani, Kavitha.V, Yazhini.G, M.Shakila Banu

Department of Food Processing and Preservation Technology,Avinashilingam University for women,Faculty of Engineering,Coimbatore

* msfppt@gmail.com, aruna3110@gmail.com

Abstract

Edible films and coatings have received considerable attention in recent years because of their advantages including use as edible packaging materials over synthetic films. This could contribute to the reduction of environmental pollution. By functioning as barriers, such edible films and coatings can feasibly reduce the complexity and thus improve the recyclability of packaging materials, compared to the more traditional non-environmental friendly packaging materials, and may be able to substitute such synthetic polymer films. New materials have been developed and characterized by scientists, many from abundant natural sources that have traditionally been regarded as waste materials. The objective of this review is to provide a comprehensive introduction to edible coatings and films by providing descriptions of suitable materials, reviewing their properties and describing methods of their applications and potential uses.

Keywords: Edible film, coatings, characteristics, environmental friendly

1. Introduction

Natural polymers can be an alternative source for packaging development due to their palatability and biodegradability (Siracusa, Rocculi, Romani & Rosa, 2008). Edible coatings and films have emerged as an alternative for synthetic plastic for food applications and have received considerable attention in recent years because of their advantages over synthetic films. The main advantage of edible films over traditional synthetics is that they can be consumed with the products. There is no package to dispose and even if the films are not consumed they could still contribute to the reduction of environmental pollution. The films are produced exclusively from renewable, edible ingredients and therefore are anticipated to degrade more readily than polymeric materials. Edible films can enhance the organoleptic properties of packaged foods provided they contain various components (flavorings, colorings, sweeteners).Their use based on natural polymers and food grade additives has been constantly increasing in the food industry. The coatings/films can be produced with a variety of natural products such as polysaccharides, proteins and lipids, with the addition of plasticizers and surfactants. The functionality and performance of edible films mainly depend on their barrier, mechanical and colour properties, which in turn depend on film composition and its formation process. In the case of the edible coatings, the method of application on the product, and the capacity of the coating to adhere to the surface are the most important parameters. Food products are usually coated by dipping or spraying, forming a thin film on the food surface that acts as a semi-permeable membrane, which in turn control the moisture loss or/and suppress the gas transfer (Lin & Zhao, 2007). The films also function as carriers for antimicrobial and antioxidant agents. Production of edible films causes less waste and pollution, however, their permeability and mechanical properties are generally poorer than synthetic films (Kester and Fennema, 1986).

2. Materials Used In Edible Coatings And Films:

A great diversity of materials is used to produce edible coatings and films, but most of them can be included in one of three categories:

(1)Polysaccharides,

(2)Proteins and

(3)Lipids

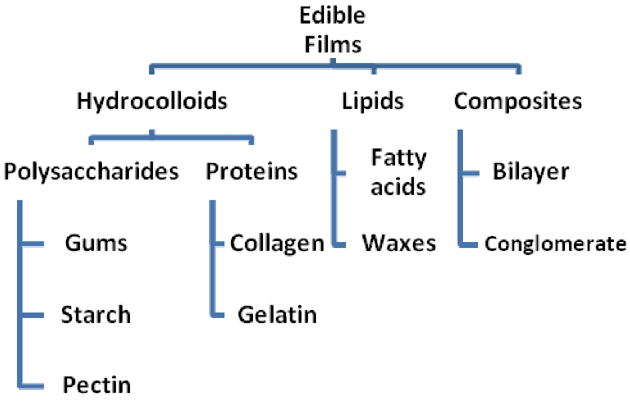

Fig 1:Types of Edible films(Han et al., 2005)

The great diversity of structural features of polysaccharides exhibit differences in the monosaccharide composition, linkage types and patterns, chain shapes, and degree of polymerization, thus influencing their physical properties. Polysaccharides, which are commercially available for use in food and non food industries as stabilizers, thickening and gelling agents, crystallization inhibitors, and encapsulating agents, etc (Stephen & Churms, 2006). The main polysaccharides used in edible coatings/films are chitosan, starch, alginate, carragennan, modified cellulose, pectin, pullulan, chitosan, gellan gum, xanthan gum, etc (Han & Gennadios, 2005).

3. Film-Forming Materials:

3.1 Hydrocolloidal Materials:

Hydrocolloids are hydrophilic polymers of vegetable, animal, microbial or synthetic origin, that generally contain many hydroxyl groups and may be polyelectrolytes (for example alginate, carrageenan, carboxymethylcellulose, gum arabic, pectin and xanthan gum). Nowadays, they are widely used as film-forming solution to perform and control the texture, flavour, and shelf-life of foods (Williams,2000). All hydrocolloids used are fully or partially soluble in water and are used principally to increase the viscosity of the continuous phase (aqueous phase) *i.e* as gelling agent or thickener (Baldwin, 1995). They can also be used as emulsifiers due to their stabilizing effect on emulsions derived from an increase in viscosity of the aqueous phase of the edible film. The kinetic motion of the oil droplets is reduced, resulting in a lower rate of flocculation and coalescence in the film.

3.2 Polysaccharide Films:

Polysaccharide films are made from starch, alginate, cellulose ethers, chitosan, carageenan, or pectins and impart hardness, crispness, compactness, thickening quality, viscosity, adhesiveness, and gel forming ability to a variety of films. These films because of the make up of the polymer chains exhibit excellent gas permeability properties, resulting in desirable modified atmospheres that enhance the shelf life of the product without creating anaerobic conditions (Baldwin et al., 1995). Additionally, polysaccharide films and coatings can be used to extend the shelf-life of muscle foods by preventing dehydration, oxidative rancidity, and surface browning, but their hydrophilic nature makes them poor barriers for water vapour (Nisperos-Carriedo, 1994).

4.Polysaccharides-Based Films:

4.1 Starch:

Starch, composed of amylose and amylopectin, is primarily derived from cereal grains like corn (maize), with the largest source of starch. Other commonly used sources are wheat, potato, tapioca and rice **.** Starch is the major carbohydrate reserve in plant tubers and seed endosperm where it is found as granules, each typically containing several million amylopectin molecules accompanied by a much larger number of smaller amylose molecules (Walstra,2003). Amylose is responsible for the film-forming capacity of starch (Claudia,2005). High amylose starch films have been made that are flexible, oxygen impermeable, oil resistant, heat-sealable, and water soluble. Films of high-amylose corn starch or potato starch was more stable during aging (Krogars,2003).Starch-based films exhibit physical characteristics similar to plastic films in that they are odorless, tasteless, colorless, non-toxic, biologically absorbable, semi-permeable to carbon dioxide, and resistant to passage of oxygen. Since the water activity is critical for microbial, chemical, and enzymatic activities, edible starch based films can retard microbial growth by lowering the water activity within the package (Wong et al., 1994).

4.2 Alginate:

Alginates are derived from seaweeds and possess good film-forming properties that make them particularly useful in food applications (Nisperos- Carriedo, 1994). Alginate has a potential to form biopolymer film or coating component because of its unique colloidal properties, which include thickening, stabilizing, suspending, film forming, gel producing, and emulsion stabilizing (Rhim,2004). Divalent cations (calcium, magnesium, manganese, aluminum, or iron) are used as gelling agents in alginate film formation. Desirable properties attributed to alginate films, include moisture retention, reduction in shrinkage improved product texture, juiciness, color, and odor of foods. Edible films prepared from alginates form strong films and exhibit poor water resistance because of their hydrophilic nature (Borchard,2005).

*4.3 Carrageenan***:**

Carrageenans are water-soluble polymers with a linear chain of partially sulphated galactans, which present high potentiality as film-forming material. These sulphated polysaccharides are extracted from the cell walls of various red seaweeds (Rhodophyceae). Carrageenan film formation includes a gelation mechanism during moderate drying, leading to a three-dimensional network formed by polysaccharide - double helices and to a solid film after solvent evaporation (Karbowiak, 2006) Recently, carrageenan films were also found to be less opaque than those made of starch (Ribeiro,2007).

*4.4 Cellulose Derivatives***:**

Cellulose derivatives are polysaccharides composed of linear chains of β (1–4) glucosidic units with methyl, hydroxypropyl or carboxyl substituents. Only four cellulose derivative forms are used for edible coatings or films: Hydroxypropyl cellulose (E463; HPC), hydroxypropyl methylcellulose (E464; HPMC), Carboxymethylcellulose (E466; CMC) or Methyl cellulose (E461; MC). Cellulose derivatives exhibit thermo-gelation. Therefore when suspensions are heated they form a gel whereas they return to their original consistency when cooled (Murray J. C. F,2000). However, cellulose derivative films are poor water vapour barriers because of the inherent hydrophilic nature of polysaccharides and they possess poor mechanical properties (Gennadios,1997). One method in enhancing the moisture barrier would be by incorporation of hydrophobic compounds, such as fatty acids into the cellulose ether matrix to develop a composite film (Morillon, 2002).

*4.5 Pectin***:**

Pectins are a group of plant-derived polysaccharides that appear to work well with low moisture foods, but are poor moisture barriers (Baldwin et al, 1997). Pectin (E440) is a heterogeneous grouping of acidic structural polysaccharides, found in fruit and vegetables and mainly prepared from citrus peel and apple pomace. This complex anionic polysaccharide is composed of β-1,4-linked D-galacturonic acid residues, wherein the uronic acid carboxyls are either fully (HMP, high methoxy pectin) or partially (LMP, low methoxy pectin) methyl esterified.

4.6 Agar:

Agar is a hydrophilic colloid consisting of a mixture of agarose and agaropectin that have the ability to form reversible gels simply by cooling a hot aqueous solution. Used extensively in microbiological media to provide firmness, agar exhibits characteristics that make it useful for coating meats. It forms strong gels characterized by melting points far above the initial gelation temperature (Natrajan & Sheldon, 2000;Whistler & Daniel, 1985). Agar gel melts on heating and resets on cooling. Because of its ability to form very hard gels at very low concentrations and the simplicity of the extraction process (Stanley,1995), agar has been used extensively as a gelling agent in the food industry. However, despite its biodegradability and its enormous gelling power, agar has not been used widely due to poor aging. Both photodegradation and fluctuations in ambient temperature and humidity alter agar crystallinity, leading to formation of micro-fractures and polymer embrittlement (Freile-Pelegrin,2007). The influence of agar on the structure and the functional properties of emulsified edible films has been recently studied by Phan The *et al.,(2009).*

4.7 Chitin/Chitosan:

Chitosan is an edible and biodegradable polymer derived from chitin, the major organic skeletal substance from crustacean shells. This is the second most abundant natural and non-toxic polymer in nature after cellulose (Shahidi, ,1999).Some desirable properties of chitosan are that it forms films without the addition of additives, exhibits good oxygen and carbon dioxide permeability, as well as excellent mechanical properties and antimicrobial activity against bacteria, yeasts, and molds (Var Tiainen et al., 2004). However, a major drawback of chitosan is its poor solubility in neutral solutions. The required degree of deacetylation to obtain a soluble product must be 80–85% or higher (Park,2002). Chitosan products are highly viscous, resembling natural gums (Peniston,1980). Chitosan can form transparent films to enhance the quality and extend the storage life of food products (Ribeiro,2007). Pure chitosan films are generally cohesive, compact and the film surface has a smooth contour without pores or cracks (Coma, 2002).

4.8 Gums:

Gums in edible-film preparation are used for their texturizing capabilities. All gums are polysaccharides composed of sugars other than glucose. Gums are differentiated into three groups (Williams,2000): exudate gums (gum Arabic; mesquite gum), the extractive gums (from endosperm of some legume seeds or extracted from the wood: guar gum) and the microbial fermentation gums (xanthan gum). In edible-forming preparations, guar gum (E 412) is used as a water binder, stabilizer and viscosity builder. Gum arabic (E 414), owing to its solubility in hot or cold water, is the least viscous of the hydrocolloid gums. Xanthan gum (E 415) is readily dispersed in water, hence high consistency is obtained rapidly in both hot and cold systems. A blend of guar gum, gum arabic and xanthan gum provided uniform coatings with good cling and improved adhesion in wet batters (Mei,2002). The mesquite gum forms films with excellent water vapor barrier properties when small amounts of lipids are added in their formulation (Diaz-Sobac,2002).

5. Method Of Application Of Edible Film And Coatings:

5.1 Dipping:

Nowadays, dipping is a common method for applying coatings on fruits and vegetables (Vargas,2008). The coating is made by dipping in a coating solution with properties such as density, viscosity and surface tension, as well as food withdrawal speed from the coating solution (Cisneros-Zevallos,2003). Generally the food was dipped into the film-forming solutions between 5 and 30s (Ayranci,1997) as represented in figure 2.

5.2 Brushing:

However, the brushing method for the application of film solution to fresh beans and strawberries was found to be better than wrapping and dipping methods in terms of reducing the moisture loss (Ayranci,1997).An example of application of film solution by brushing method is represented in figure 3.

5.3 Spraying:

In the food industry, coating by spraying is the conventional method generally used when the coating-forming solution is not very viscous. Indeed, highly viscous solution cannot be or very easily sprayed. Thus only dipping techniques can be applyied giving high thickness to the coating. Initially, in the case of plan jet, the spray exits the nozzle as a two dimensional sheet of fluid. This sheet then breaks up into a series of cylindrical ribbons which eventually undergo the same type of breakup as laminar capillary jets *(Stone.,1994)*. The control of the final drop size and therefore of the quality of the coating depend on spray gun and nozzle temperature, air and liquid flow rate, humidity of incoming air and of the polymer solution *(Bergeron,2003).* Nowadays, programmable spray systems are available for automation during such operations. Classic spraying system can produce a fine spray with relatively drop-size distribution up to 20 μ m . Futhermore, other different factors are critical in the formation of polymeric films by spraying systems, such as drying time, drying temperature, drying method, etc.

5.4 Solvent Casting:

Solvent casting is the most used technique to form hydrocolloid edible films. Water or water– ethanol solutions or dispersions of the edible materials are spread on a suitable substrate and later dried . During drying of the films, solvent evaporation leads to a decrease in solubility of the polymer until polymer chains align themselves to form films. The choice of the substrate is important to obtain films, which can be easily peeled without any damage after the solvent is evaporated. Generally, the films are air-dried during several hours in the ventilated oven (Bergeron,2003). Optimum moisture content (5–10% w/v) is desirable in the dried film. Film structures depend on the drying conditions (temperature and relative humidity), wet casting thickness as well as the composition of the casting solution.

5.5 Extrusion:

The application of extrusion technology to edible films, such as starch films, is another choice (Guan and Hanna 2006). The extrusion process is based on the thermoplastic properties of polymers when plasticized and heated above their glass transition temperature under low water content-conditions. The extrusion processing of polymer products often need the addition of plasticizers such as polyethylene glycol, sorbitol in an amount of 10% to 60% w/w .In comparison with the solvent casting method, the extrusion method is attractive for industrial processes since it does not require solvent addition and a time of evaporation.

6.Effect Of Edible Films On Food Products And Its Application:

In order to select edible coatings to be applied on food products two step Criteria is followed: in a first stage, to evaluate wettability values of the coating formulations (the coatings with the best values are selected); in a second stage, to determine the values of other relevant properties (e.g. high or low water vapour, oxygen or carbon dioxide permeabilities, good mechanical resistance, etc.) depending on the kind of food and on the desired effects. This allows refining the selection made in stage one and ending eventually with the best formulation for a given application. In 2007, Ribeiro et al. tested the ability of polysaccharide coatings of starch, carrageenan and chitosan to extend the shelf-life of strawberry fruit (*Fragaria ananassa*) is represented in figure 4.

The coatings and strawberries were characterized in terms of their physical properties (wettability and then oxygen permeability) in order to optimize coating composition. In both cases, to enhance the wettability of the coating solutions, The effects of application of these coatings to fresh strawberries were assessed by determining colour change, firmness, weight loss, soluble solids and microbiological growth. The results show that the edible coating leads to the improvement of strawberries firmness loss, to the decrease of mass loss and rate of microbial growth.

In 2009, Cerqueira et al., studied the utilization of coatings composed of galactomannans from two different sources (*Caesalpinia pulcherrima* and *Adenanthera pavonina*) and glycerol for application on five tropical fruits: acerola (*Malpighia emarginata*), cajá (*Spondias lutea*), mango (*Mangifera indica*), pitanga (*Eugenia uniflora*) and seriguela (*Spondias purpurea*). The wettability was determined using different aqueous galactomannan solutions (0.5 %, 1.0 % and 1.5 %) with glycerol (1.0 %, 1.5 % and 2.0 %). Also Lima et al. (2010) studied the application of coatings based on mixtures of polysaccharide (galactomannan from *C. pulcherrima* and *A. pavonina*), collagen and glycerol on mangoes and apples. The same methodology was used in order to choose one coating formulation for application on the mango and apple. Finally, the coatings were applied on fruits in order to determine their influence in gas transfer rates. Coated mangoes and apples present less O2 consumption and less CO2 production than uncoated fruits.

7.Conclusion:

The concept of edible films and coatings represents a stimulating route for creating new packaging materials. This is because edible films and coatings are available with a wide range of properties that can help to alleviate many problems encountered with foods. Edible films can be produced from materials with film forming ability. However, potential functions and applications of the films and coatings warrant increased considerations. The selected coating formulations can reduce gas transfer rates and can be therefore important tools to extend shelf life of foods. A good choice of the coating formulation is essential for the durability and maintenance of the coating on the food products. The determination of wettability is therefore fundamental for the correct application of edible coatings.

References

Baldwin, E. A.; Nisperos-Carriedo, M. O.; Baker, R. A.(1995) *Crit. Rev. Food Sci.*

Borchard, W.; Kenning, A.; Kapp, A.; Mayer, C. (2005) *Int. J. Biol. Macromol.*

Claudia, A. R. B.; Bello-Perez, L. A.; Gacia, M. A.; Martino, M. N.; Solorza-Feria, J.;Zaritzky, N. E.(2005) *Carbohyd. Polym.*

Cerqueira, M. A.; Lima, A. M.; Souza, B. W. S.; Teixeira, J. A.; Moreira, R. A.; Vicente, A. A. *J.(2009). Agr. Food Chem.*

Cisneros-Zevallos, L.; Krochta, J. M. *J. (2003) Food Sci.*

Diaz-Sobac, R.; Garcia, H. S.; Beristain, C.I.; Vernon-Carter, E. J. *J. (2002).Food Process. Pres.*

Gennadios, A.; Hanna, M. A.; Kurth, B.(1997) *LWT-Food Sci. Technol.*

Han, J. H., & Gennadios, A. (2005). Edible films and coatings: a review. In: J. Han, *Innovations in Food Packaging* (pp. 239-259): Elsevier Science & Technology Books.

Kester and Fennema.(1986). *Edible films and coatings: characteristics and properties. International Food Research Journal* 15(3): 237-248 (2008).

Krogars, K.; Heinamaki, J.; Karjalainen, M.; Rantanen, J.; Luukkonen, P.; Yliruusi, J. *Eur,J. Pharm. Biopharm.(* 2003)

Karbowiak, T.; Debeaufort, F.; Champion, D.; Voilley, A.(2006). *J. Colloid Interf. Sci.*

Morillon, V.; Debeaufort, F.; Bond, G.; Capelle, M.; Voilley,(2002) A. *Crit. Rev. Food Sci.*

Murray J. C. F.(2000) In *Handbook of hydrocolloids*; Phillips G.; Willians P.; Ed.; CRC Press,Cambridge, England

Nisperos-Carriedo, M. O. (1994): Edible coatings and films based on polysaccharides. In J. M. Krochta, E. A. Baldwin, & M. O. Nisperos- Carriedo (Eds.), Edible coatings and films to improve food quality (pp. 305– 335). Lancaster, PA: Technomic Publishing Company.

Phan The, D.; Debeaufort, F.; Luu, D.; Voilley, A(2005). *J. Agr. Food Chem.*

Park, S. Y.; Marsh, K. S.; Rhim, J. W. *J. (2002).Food Sci.*

Ribeiro, C.; Vicente, A. A.; Teixeira, J. A.; Miranda, C.(2007) *Postharvest Biol. Tec.*

Ribeiro, C.; Vicente, A. A.; Teixeira, J. A.; Miranda, C.(2007). *Postharvest Biol. Tec.*

Siracusa., Rocculi., Romani & Rosa.(2008). Strategies for Evaluation of Edible Coating Formulations -Applications on Food Quality and Safety, p.8-14

Stanley, N. F.(1995) In *Food polysaccharides and their applications*; Stephen A. M.; Ed.; New York, Marcel Dekker.

Stephen, A. M., & Churms, S. C. 2006. : A. M. Stephen, G. O. Phillips, & P. A.Williams, Food Polysaccharides and Their Application (pp. 1-24). Boca Raton: CRC Press, Taylor & Francis.

Shahidi, F.; Arachchi, J. K. V.; Jeon, Y. J. (1999).*Trends Food Sci. Tech.*

Stone, H. A. (1994).*Annu. Rev. Fluid Mech.*

Vargas, M.; Albors, A.; Chiralt, A.; Gonzalez-Martinez,C.(2006)*Postharvest Biol. Tec.*

Williams, P. A.; Phillips, G. O. In Handbook of hydrocolloids; Phillips G.; Willians P.; Ed.; CRC Press, Cambridge, England, 2000; pp 1-19.

Wong, D. W. S., Camirand, W. M., & Pavlath, A. E. (1994): Development of edible coatings for minimally processed fruits and vegetables. In J. M. Krochta, E. A. Baldwin, & M. O. Nisperos-Carriedo (Eds.), Edible coatings and films to improve food quality (pp. 65–88). Lancaster, PA: Technomic Publishing Company.

Whistler, R. L., & Daniel, J. R. (1985): Carbohydrates.In O. R. Fennema (Ed.), *Food chemistry* (2nd ed.) (pp. 69–137). New York: Marcel Dekker.

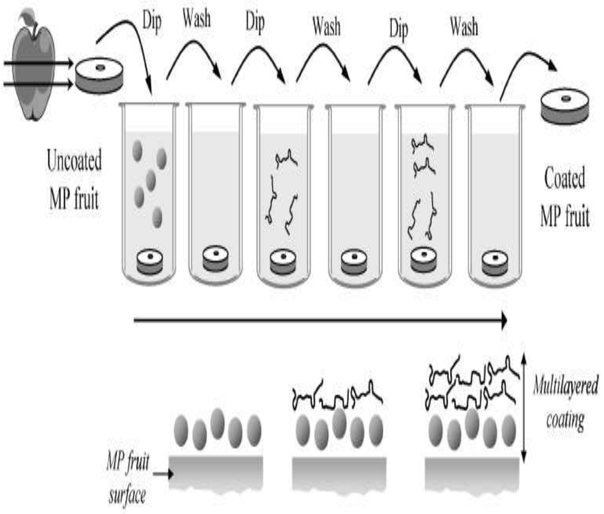

Fig2:Schematic representation of coating a minimally processed (MP) fruit with a multilayered edible coating by using the layer-by-layer assembly with three dipping and washing steps

Fig3:Application of film solution on cucumber by brushing method

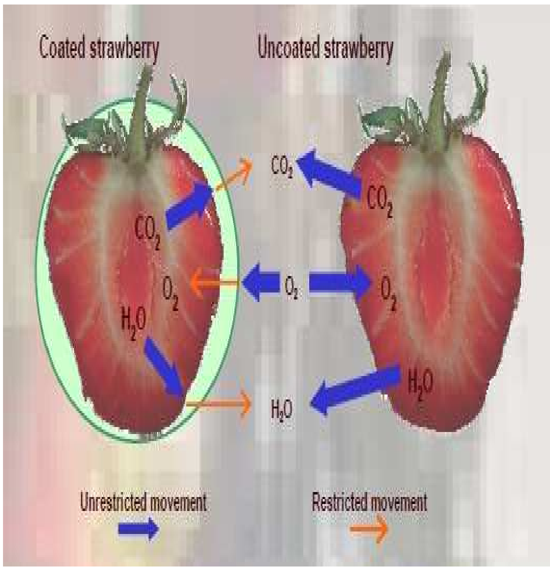

Fig4:Potential of an edible coating to act as a gas and moisture barrier

Fig 5:Coatings can reduce physical changes in the fresh-cut product

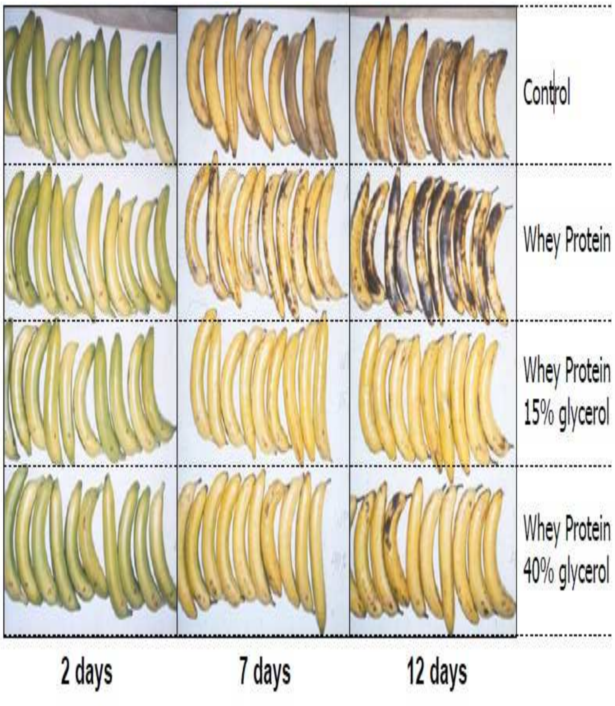

Fig 6:Bananas coated with Whey Protein & Glycerol

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