Eat your food with wrappers

By

Harya Krishna V.

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COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA - 680656

THRISSUR

DECLARATION

I, Harya Krishna V. (2018-12-016) declare that the seminar entitled "Eat your food with wrappers" has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

Vellanikkara
25-01-2020

Harya Krishna V.
(2018-12-016)

CERTIFICATE

This is to certify that the seminar report entitled **"Eat your food with wrappers"** has been solely prepared by **Harya Krishna V. (2018-12-016)**, under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

Vellanikkara

25-01-2020

Ms. Meagle Joseph P.

(Major advisor)

Professor and Head

Department of Post Harvest Technology

College of Horticulture, Vellanikkara

CERTIFICATE

This is to certify that the seminar report entitled "**Eat your food with wrappers"** is a record of seminar presented by **Harya Krishna V. (2018-12-016)** on 28th November, 2019 and is submitted for the partial requirement of the course PHT 591.

Dr. K. Anil Kuruvila
Professor
Department of Agricultural Economics
College of Horticulture, Vellanikkara

Dr. Reshmy Vijayaraghavan
Assistant Professor
Department of Plant Pathology
College of Horticulture, Vellanikkara

Dr. Sangeeta Kutty M.
Assistant Professor
Department of Vegetable Science
College of Horticulture, Vellanikkara

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Eat your food with wrappers

1. Introduction

Food wastage is reported to be approximately 1.3 billion tonnes per year globally, in which fruits and vegetables contribute to 50 per cent loss (FAOUN, 2015). Although food processing sector plays a key role in reducing the loss, according to MoFPI (2018), about 15 per cent fruit and vegetable wastes are generated by this sector. Moreover, packaging materials of processed food products made of polythene are posing great threat to environment. One of the best solutions for these problems is to develop edible food packaging materials such as films and coatings from the surplus fruits, vegetables and residues of processing industries, which are green alternatives for a sustainable life on earth.

Edible films and coatings are a type of packaging material that could be eaten, or has the ability to biodegrade efficiently as the food it contains. Both films and coatings which regulate the transfer of moisture, oxygen, carbon dioxide, lipid, aroma and flavour compounds in food systems, can increase shelf-life of food products, improve food quality and decrease amounts of conventional synthetic packaging materials needed to preserve and protect foods, as well as improve package recyclability by decreasing the need for coating, laminating or coextrusion (McHugh *et al*., 1996). The edible films are stand-alone structures whose thickness ranges from 0.05 to 0.25 mm, used for wrapping food materials and coatings are directly applied on food surface, with a thickness of less than 0.30mm (Kadzinska *et al*., 2019).

The food grade biopolymers extracted either from plant or animal sources like poly saccharides, proteins, lipids and their composites are the materials used for making edible packaging materials. Moreover seaweed as such can be used for the purpose. Fruit and vegetables, the protective foods gifted by nature are used for making edible food packaging materials. Among all the sources mentioned fruit and vegetables receives attention because of their richness in nutrients. Fruit and vegetable residues, pomace, extracts, juice and purees along with suitable binding agent and plasticizer, have good matrix forming properties to produce edible packaging material with good physical and mechanical properties. The edible films based on fruit and vegetable are alternative means of nutrient intake, including pigments and polyphenols with antioxidant capacity.

2. History

The history of edible films and coatings started from the 12th century, when Chinese and Europeans used wax on citrus fruits and meat lard. Later in 15th century Japanese used skin of boiled soy milk, called Yuba as edible film. In 1986, US started commercial production of biopo lymers as edible coatings (Debeaufort, *et al*., 1998).

The idea of edible films and coatings based on fruits and vegetables was originated during the last 20th century fledged with several enthusiastic minds. Earlier the research has focused on incorporation of fruit and vegetable purees into sheets, commonly called ‘‘leathers,’’ without regard to potential barrier properties (McHugh *et al*., 1996). Taga *et al*. (1993) patented a method for manufacturing a snack food by drying fruit or vegetable pastes. Later, savory vegetable leather was produced from vegetable purees and other ingredients (Rudolph *et al*., 1994). Such studies have not revealed the potential of fruit and vegetable purees in the formation of edible mass transfer barrier films and coatings.

The potential of fruit and vegetable purees for the formation of edible mass transfer barrier films and coatings was first recognized by McHugh T. H., ARS scientist of USDA. McHugh *et al.* (1996) produced the first edible films based on fruit purees (McHugh *et al*., 2006, 2012). Later in 2006, in collaboration with their research partner, Origami foods® they commercialized these fruit wraps as sushi wraps and in 2011, they got patent on "fruit and vegetable films and uses thereof". Since then, several studies have been carried out on the development of films made up of several fruits and vegetables.

Plate 1: T. H. McHugh

Plate 2: Fruit and vegetable wraps

Plate 3: Sushi making

Plate 4: Beet root and guava puree films

Table 1: Fruit based edible packaging materials

Common Name	**Scientific Name**	**Form of Fruit used**	**Form of the final product**	**References**
Acai	*Euterpe oleracea Mart*.	Puree	Film	Espetia *et al*., 2014
Apple	*Malus domestica* Borkh. *M.pumila* Mill. *Pyrus malus* L.	Puree Pomace	Film, Coating, Leather Film, Coating	McHugh *et al*., 1996, Shin *et al*., 2014
Apricot	*Prunus armeniaca* L.	Puree	Film	McHugh *et al*., 1996
Banana	*Musa paradisiaca L*. *M. cavendishii* Lamb.	Puree Pomace Flour	Film, Heat-sealed sachet	Martelli *et al*., 2014
Barbados cherry (acerola)	*Malpighia emarginata* DC. *M. glabra* L. *M. punicifolia* L.	Puree Fruit extract	Film	Souza *et al*., 2011
Cashew apple	*Anacardium occidentale* L.	Fruit extract	Film	Eca *et al*., 2015
Cranberry	*Vaccinium macrocarpon* Aiton	Pomace extract	Film	Park and Zao , 2006
Gooseberry	*Riber uva-crispa* L.	Puree	Film	Xu *et al*., 2017
Grape	*Vitis vinifera* L.	Pomace Extract Clarified juice	Film Leather	Mattoso *et al*., 2015
Guava	*Psidium guajava* L.	Puree	Film	Zhu *et al*., 2014

Indian gooseberry	*Phyllanthus emblica* L.	Puree Fruit extract	Film, Coating	Suppakul *et al*., 2016
Mango	*Mangifera indica* L.	Puree Pomace	Film, Heat-sealed sachet, Coating	Andrade *et al*., 2014 Dantas *et al*., 2015
Orange	Citrus sinensis	Pomace	Film	Andrade *et al*., 2016
Papaya	*Carica papaya* L.	Puree Extract	Film, Heat-sealed sachet	Otoni *et al*., 2014
Passion fruit	*Passiflora edulis* Sims.	Puree Pomace	Film	Andrade *et al*., 2016
Peach	*Prunus persica* (L.) Batsch	Puree	Film	Otoni *et al.*, 2015
Pear	*Pyrus communis* L.	Puree	Film	McHugh *et al*., 1996
Pomegranate	*Punica granatum* L.	Juice, Juice concentrate	Film, leather	Eca *et al*., 2015
Strawberry	*Fragaria ananassa* Duch. *F. vesca* L.	Puree Fruit extract	Film	Peretto *et al*., 2014

Table 2: Vegetable based edible packaging materials

Common Name	**Scientific Name**	**Form of Vegetable used**	**Form of the final product**	**References**
Broccoli	*Brassica oleracea var. capitata*	Puree	Film	McHug and Olsen, 2004

Cabbage	*Brassica oleracea var. capitata*	Residue	Film	Sun *et al*., 2010
Carrot	*Daucus carota* L.	Puree, Pomace	Film, Coating	Lahnke *et al*., 2015
Celery	*Apium graveolens* L.	Puree	Film	Wang *et al*., 2012
Courgette	*Cucurbita pepo* L.	Pomace	Film	Fai *et al*., 2016
Cucumber	*Cucumis sativus* L.	Pomace	Film	Mariniello *et al*., 2007
Lettuce	*Lactuca sativa* L.	Pomace	Film	Andrade *et al*., 2016
Mint	*Mentha sp*	Extract	Film	Andrade *et al*., 2016
Potato	*Solanum tuberosum*	Pomace	Film, Coating	Ferreira *et al*., 2016
Pumpkin	*Cucurbita moschata*	Residue	Film	Zhang and Fu, 2010
spinach	*Spinacea oleracea* L.	Pomace	Film	Ferreira *et al*., 2016
Tomato	*Solanum lycopersicum* L.	Puree	Film, Coating	Du *et al*., 2009
Watermelon	*Citrullus lanatus* (Thunb.)	Puree, Pomace	Film	Mottoso *et al*., 2015

3. Method of preparation of fruit and vegetable based films

3.1 Components of fruit and vegetable based films

Edible films and coatings should have at least two components: a bio macromolecule based matrix able to form a cohesive structure and a solvent, usually water. A plasticizer is often required for reducing brittleness inherent to most biopolymers. Some other components, such as cross linkers and nano reinforcements can be incorporated to improve barrier and tensile properties of film (Kadzinska *et al*., 2019).

3.1.1 Fruits/ Vegetables: Puree, pomace, and extract

Fruits and vegetables have good matrix forming properties because of the rich source of polysaccharides and proteins. In addition, they provide nutritional and sensory properties to the edible films. The films produced only with fruit purees are peach, pear, apricot, apple (McHugh *et al*., 1996), mango (Azeredo *et al*., 2009) and banana (Martelli *et al*., 2015).

Pomace extracts, which contain pectin, cellulose, pigments and other functional compounds, may also be used as a novel film-forming material for making edible films and coatings. Such edible films and coatings would provide additional benefits like unique fruit flavour and colour, thus attracting more potential applications (Park and Zhao, 2006).

3.1.2. Binding agent

Films which are exclusively made from fruit or vegetable puree show poor consistency, mechanical strength and barrier properties. Hence edible hydrocolloids such as polysaccharides and proteins are added as binding agents to improve its physical properties (Otoni *et al*., 2017). The most widely used binding agent in fruit and vegetable based film is pectin.

If the addition of a single biopolymer is not sufficient, two or more macromolecules may be combined into blends and used. These bio macromolecules can be extracted from plants (starch, pectin, and cellulose), animals (collagen, gelatin, and chitosan), microorganisms (bacterial cellulose), and algae (including alginate and carrageenan).

Gelatin obtained from the partial denaturation of collagen, has good gelling and film forming properties along with a melting temperature, close to that of the human body (Otoni *et al*., 2012). So they are known to exhibit good mechanical and gas barrier properties, but they are generally too brittle, making the addition of plasticizers essential for their practical application (Wang *et al*., 2011).

The chemical structures of the hydrocolloids are expected to influence their film-forming abilities. Low-methoxyl pectin, for instance, was shown to produce stronger and less extensible cranberry pomace added films than its high methoxyl counterpart (Park and Zhao 2006). The substitution degrees in cellulose derivatives, such as carboxymethylcellulose (CMC), hydroxypropyl methylcellulose (HPMC), and methylcellulose (MC), amino acid sequences in proteins, deacetylation degrees in chitosan, and amylose/amylopectin ratio in starch etc., are critical factors to determine the physical behavior of films.

3.1.1.3 Plasticizers

Plasticizers are non-volatile macromolecules having low molecular weight which may be internal or external plasticizers. Internal plasticizers are part of polymer bio macromolecule, like the fruit purees of papaya, and mango itself acting as plasticizers, due to the presence of natural sugars. External plasticizers, on the other hand are the biomolecules which do not chemically bind to the backbone chain of the film forming matrix (Sothornvit and Krochta 2005). They are intended to make polymer processing easier and/or to modify the properties of the resulting material. External plasticizers, particularly, reduce the polymer chain-to-chain interaction level by positioning themselves between polymer molecules and thus separating adjacent chains apart. This action leads to materials with reduced brittleness and stiffness as well as increased flexibility, stretchability, and toughness (Han and Aristippos 2005; Sothornvit and Pitak, 2007). The most used plasticizer in fruit and vegetable based films is glycerol. According to Wang et al. (2011), carrot puree added Carboxy methyl cellulose (CMC), gelatin and starch based films found to be brittle and rigid with holes and cracks, whereas glycerol plasticized films were more flexible.

On the other hand, Shen *et al*. (2015), reported better results for sorbitol than glycerol when plasticizing polyvinyl alcohol (PVOH)-sugar beet pulp edible films, which otherwise were too brittle and cracked on the casting surface. Glycerol-plasticized films were wet and difficult to peel from the casting surface. As a matter of fact, high glycerol contents have been reported to migrate to film surface, exudate, and form sticky films (Wang *et a*l., 2011).

Other food-grade plasticizers may also be used for edible film production, including low-molecular weight sugars (fructose-glucose syrups and honey), polyols (glyceryl derivatives and propylene glycols), lipids and derivatives (including phospholipids, fatty acids, lecithin, oils, and waxes), and water (Han and Aristippos 2005; Sothornvit and Krochta 2005). Corn syrup has been used both as plasticizer and sweetener to acerola films and coatings, which otherwise were too acidic (Azeredo *et al*.,2012; Azeredo and *et al*., 2012b).

3.1.1.4 Fillers

Most biopolymers commonly used as binding agents in edible films based on fruits and vegetables exhibit poor mechanical resistance, barrier and thermal properties. Materials featuring these characteristics have limited commercial applicability for food packaging purposes. A feasible strategy to overcome this technical hurdle is the production of edible composites/nano composites by addition of reinforcing fillers.

Polymer nano-reinforcements are nanoparticles added to polymers in order to obtain nanocomposites with enhanced mechanical and other physical properties. A uniform nanoparticle dispersion within a polymer matrix leads to a very large matrix/filler interfacial area, which changes the molecular mobility, the relaxation behaviour, resulting in improved thermal and tensile properties of the material.

Fillers with high aspect ratios are particularly interesting because of their high specific surface area, providing better reinforcement effects. Polysaccharide nanoparticles, especially cellulose nanostructures have been presented as good renewable and biodegradable nanofillers, due to their partly crystalline structures, providing an extremely high strength as well as good reinforcement effects (Azeredo *et al*., 2017). Cellulose nanocrystals (CNCs), microcrystalline cellulose (MCC), montmorillonite (MMT) chitosan nanoparticles etc., are the commonly using fillers in fruit and vegetable based edible films.

3.1.1.5 Functional additives

Edible films based on fruits and vegetables may carry functional compounds to improve their sensory, nutritional and antimicrobial properties. The functional compounds are natural essential oils and antioxidants extracted from plants. The incorporation of essential oils and oil compounds produced as secondary metabolites by numerous plant species provide active food packaging.

3.1.1.6. Other additives

Fruits and vegetables rich in phenolic components are readily subjected to the action of polyphenol oxidase upon cutting, peeling, and/or pulping. It leads to the browning, an undesirable change both in sensory and nutritional properties (Yoruk and Marshall, 2003). Other browning reactions like Maillard reaction, may also take place in foods, when subjected to higher temperature. Browning can be prevented by the addition of browning inhibitors like ascorbic and citric acid in films based on fruits having high phenolic content. (Martins *et al*., 2000; Yoruk and Marshall 2003)

Crosslinking agents are another class of additives that may be present in fruit and vegetable based films. Crosslinking of polymer matrices links adjacent chains together by covalent bonds, usually resulting in stronger and less permeable films (Porta *et al*., 2011). This crosslinking can be achieved either physically (Benbetta¨ıeb *et al*., 2016), by submitting the macromolecule to physical treatments that induce formation of a tridimensional network, such as gamma (Porta *et al*., 2011) and ultraviolet-B (Otoni *et al*., 2012) radiations or chemically, by adding food-grade crosslinking agents, such as enzymes, particularly transglutaminase (Porta *et al*., 2011).

Some fruit and vegetable purees itself have natural cross linking agents. Approximately one fourth of wine grape pomace weight, has been assigned to cross linking agents, including minerals such as ions of calcium, magnesium and iron, proteins as well as organic, amino, and phenolic acids (Deng and Zhao, 2011). These naturally occurring cross linkers could eliminate the need of additional cross linkers to produce films from wine grape pomace extract.

3.2 Film forming procedure

3.2.1. Preparation of film forming formulations

The first step of film-forming protocol is the production of a film-forming solution, dispersion or suspension, commonly called film forming formulations (FFFs). All components of the film are intimately mixed in order to obtain homogeneous edible films.

3.2.2. Degassing of film-forming formulations

Degassing and defoaming of FFFs is an important step in the production of polymer films, in order to remove air micro bubbles, which, if left suspended, tend to remain entrapped within the dried film, acting as structural defects that cause mechanical failures. After degassing the FFF either applied directly on fruit surface as coating or casted for making films.

3.2.3. Casting

Casting is the method of making films preferred over other film forming procedures due to thermo sensitive behaviour of biopolymers. Production of edible films based on fruits and vegetables can be done by both bench casting and continuous casting.

3.2.3.1. Bench casting

Film production by bench casting consists in pouring a FFF on rimmed or plain plates from varying materials. The final film thickness is controlled by the amount of suspension poured on rimmed plates or by using a draw-down bar for plain plates. The basic principle of bench casting is solvent removal through evaporation. Drying is usually carried out at room temperature or in air circulation ovens at temperatures not higher than 30 to 40 °C, for 12 to 48 h. The most remarkable disadvantage of bench casting is their long drying period.

Plate 5: Film forming solution

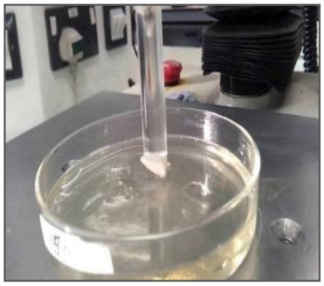


Plate 6: Pouring into petri plate

Plate 7: Detaching of film

3.2.3.2. Continuous casting

Casting for commercial purposes is done by continuous casting. It can be carried out on steel belt conveyors or on a coating line. In seat belt conveyors, solutions are uniformly spread on a continuous steel belt that passes through a drying chamber. The dry film is then stripped from the steel belt and wound into mill rolls. One advantage of this technique is the ability to cast aqueous solutions directly onto the belt surface, optimizing uniformity, heat transfer, and drying efficiency, while avoiding expense of a separate substrate.

In a coating line, solutions are continuously spread onto a moving substrate such as polyester or coated paper with a blade whose height can be adjusted to control film thickness. The coated substrate then passes through a drying chamber. The dry film is wound into rolls while still adhered to the substrate. The most attractive feature this type of casting is their shorter drying time

Plate 8: Feeding of FFF

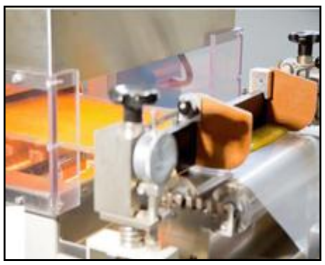


Plate 9: Blade of controlled thickness

Plate 10: Infra-red radiation drying

Plate 11: Winding roll

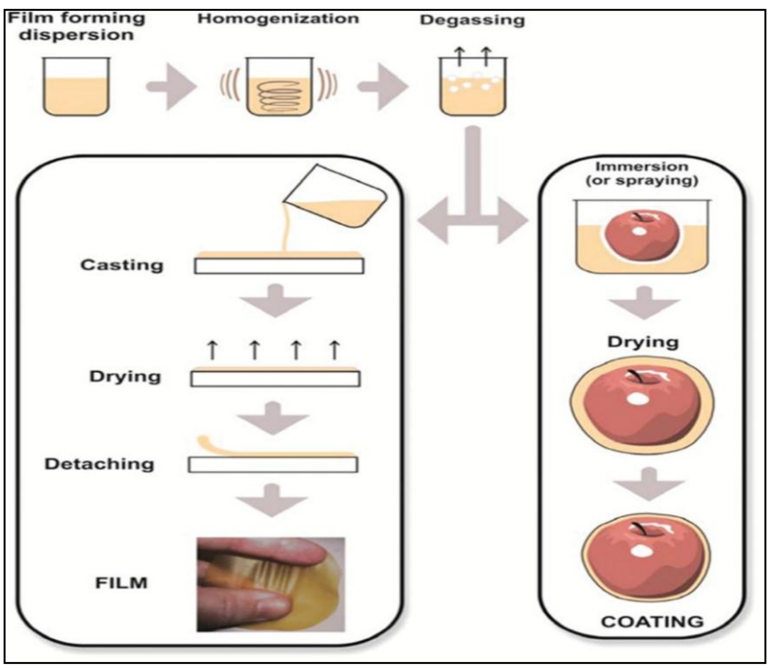


Plate 12: Procedure of film/coating preparation

4. Properties of fruit and vegetable based edible films

Fruit and vegetable based films are sustainable, as they are from biodegradable, renewable resources. It is a good packaging material due to low moisture content, good stability, flexibility, barrier properties etc. with an additional benefit of high nutrient status. Along with this colourful flavourful nature, the functional additives added like essential oils and antioxidants impart active packaging functions.

4.1 Nutritional properties

Among the exclusive characteristics of edible films based on fruits and vegetables, their nutritional and health-promoting functional properties are of prime importance as shown in Table 3.

Table 3: Nutrient properties of fruit and vegetable based edible packaging materials

Film	TPC (mg/g)	TCC (mg/g)	TFC (mg/g)	Vitamin C (mg/g)	β-carotene (μg/g)	References
Mango-acerola	89.17- 168.80	0.03 - 0.07	-	0.6	-	Souza *et al*., 2011
Mango puree-yerba mate extract	43.41-178.53	21.15 - 48.10	0.02 - 0.06	-	21.15 -48.10	Reis *et al*., 2015

Thus the films made from fruits and vegetables act as an alternative means of nutrient supply.

4.2 Mechanical properties

Good mechanical properties are among the basic requirements for edible films to be used as food packaging, as poor flexibility or strength may lead to premature failure or cracking during production, handling, storage or use. Most widely studied mechanical properties of fruit and vegetable based films are tensile strength, elastic modulus and elongation at break. The films having higher tensile strength and elastic modulus with lower elongation break shows the good mechanical strength. Fruit and vegetable based films have a comparable tensile property with synthetic food packaging materials.

Table 4: Tensile properties of films

Film	Tensile Strength (TS) (MPa)	Elastic Modulus (EM) (MPa)	Elongation (E) (%)
Fruit and vegetable	0.03 - 30.00	0.003 - 1000.00	1.80 - 217.00
LDPE	8.00 - 10.00	150.00 - 340.00	300.00 - 900.00
HDPE	19.00 - 31.00	-	20.00 - 50.00
PVC	42.00 - 55.00	2800.00	-
PS	31.00 - 49.00	2700.00 - 3500.00	2.00 - 3.00

The mechanical properties of edible films strongly depend on their composition. Vegetable films are expected to be stronger and less extensible than fruit films because of their higher ratios of dietary fibers to total sugars (McHugh and Olsen 2004). The mechanical properties of edible films based on fruits and vegetables can be adjusted as needed by addition of binding agents, fillers, cross linkers and/or plasticizers. Higher fruit and vegetable contents are expected to lead to lower mechanical strength and stiffness as well as greater extensibility because of the plasticizing effects of short-chain sugars (Sothornvit and Pitak 2007; Lorevice *et al*., 2012; Martelli *et al*., 2013; Lorevice *et al*., 2014; Otoni *et al*., 2014, 2015; Reis *et al*., 2015).

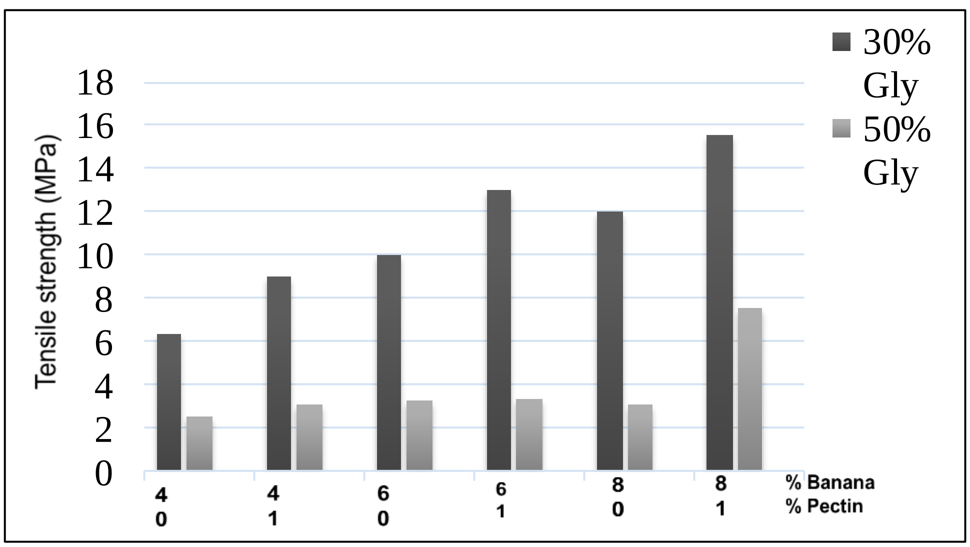


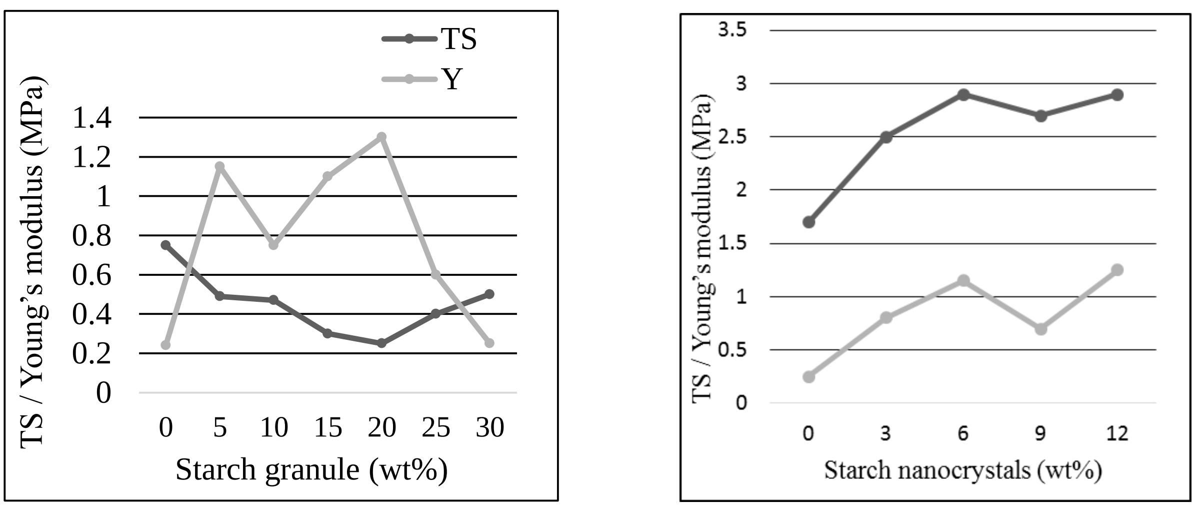
Figure 1: Effect of banana flour, pectin and glycerol content on tensile strength of film

In a study conducted by Sothornvit and Pitak (2007), banana flour films showed an increase in tensile strength with increase in their concentration at 30 per cent glycerol content. When the glycerol content was increased to 50 per cent it reduced the strength, due to the plasticizing effect of glycerol. The addition of binding agents, fillers, and cross linking agents to reinforce edible films based on fruits and vegetables improved their mechanical strength. The reinforcement of 0.2 per cent chitosan nano particles into banana puree films resulted in a higher tensile strength and elastic modulus (Martelli *et al*., 2013).

Table 5: Effect of chitosan nanoparticle on tensile strength of banana puree film

	Pectin (%)	Chitosan nanoparticle (%)	TS (MPa)	EM (MPa)
Banana puree (4.5%) + Glycerol (5%)	0	0	1.1 ± 0.1^{a}	11 ± 1^{a}
	0	0.2	0.9 ± 0.2^{a}	14 ± 5^{a}
	0.5	0	3.2 ± 0.5^{c}	21 ± 3^{b}
	0.5	0.2	4.5 ± 0.7^{d}	43 ± 3^{c}

Condes *et al*. (2018), incorporated amaranth starch granules and amaranth starch nanocrystals separately on to amaranth protein films. The film reinforced by amaranth starch nanocrystals showed an increase in both tensile strength and elastic/Young's modulus than that of the starch granules, due to homogenous distribution of nanocrystals among protein matrix



2(a) 2(b)

Figure 2: Tensile properties of amaranth starch (a) granule film (b) nanocrystal film

4.3 Thermal properties

Thermal stability of film is decided by their glass transition temperature (Tg), the temperature at which the film change their glassy state in to more viscous rubbery state. Above that temperature it loses its properties. So, films with higher Tg are preferable.

Guava puree added hydroxy propyl methyl cellulose (HPMC) film, increased its Tg from 169 ^{0}C to 189 ^{0}C (Lorevice *et al*., 2012). Thus thermal stability of the films can be improved and it can be used in high temperature condition like microwave ovens during cooking, which works at higher temperature.

Table 6: Thermal properties of guava puree incorporated films

Types of films	**Tg**
HPMC	169 ^{0}C
HPMC + Nanoparticles (0.2 % Chitosan)	183 ^{0}C
HPMC + Guava puree (10%)	189 ^{0}C
HPMC + Nanoparticles (0.2 % Chitosan) + Guava puree	184 ^{0}C

4.4 Barrier properties

4.4.1. Moisture barrier

The biomolecules present in fruits and vegetable are highly polar and hydrophilic, there by poor barriers of water (Deng and Zhao, 2011; Azeredo *et al*., 2012a). The water vapour permeability (WVP) of these films ranges from 0.10-13.57 gmm/m^2/h/kPa.

Strategies to improve the water barrier properties of edible films based on fruits and vegetables include addition of hydrophobic substances, reinforcement of nano materials as fillers etc. The WVP of mango puree edible films was reduced from 2.66 gmm/m^2/h/kPa to 1.67 gmm/m^2/h/kPa, when 36 per cent of cellulose nanofiber (CNF) was added (Azeredo *et al*., 2009). Similarly, the WVP of acerola puree edible films was decreased from 1.07 g mm/m^2/h/kPa to 0.68 g mm/m^2/h/kPa upon the addition of 10 per cent of Cellulose nanocellulose(CNC) or montmorillonite (MMT) nanoclay (Azeredo *et al*., 2012). The addition of chitosan nanoparticles reduced the WVP of guava puree edible films from 2.09 to 1.58 g mm/m2/h/kPa (Lorevice and others 2012) as well as that of banana puree edible films from 3.03 to 1.90 g mm/m2/h/kPa (Martelli *et al*., 2013). These outcomes have been attributed to the increased tortuosity of the diffusive pathway, making water vapor diffusion slower (Azeredo *et al*., 2009; Azeredo *et al*., 2012).

Apple skin polyphenols were assumed to form hydrogen and covalent bonds with pectin and/or apple puree polar groups, resulting in less hydrophilic materials that, consequently, were less permeable to water vapour (Du *et al*., 2011). The aforementioned strategies involve the addition of hydrophilic fillers, but the incorporation of hydrophobic additives, lipids, for instance, as an approach for obtaining improved water barrier properties has been suggested by McHugh *et al*. (1996), and corroborated in later investigations on the addition of vegetable oils, fatty acids, and beeswax into apple puree edible films (McHugh and Senesi 2000); oregano, lemongrass, and cinnamon essential oils into apple puree edible films (Rojas-Gra¨ u *et al*., 2006);oregano essential oil, carvacrol, and cinnamaldehyde into carrot puree edible films (Wang *et al*., 2011); cinnamaldehyde nanoemulsions in to papaya puree edible films(Otoni *et al*., 2014); carvacrol and methyl cinnamate into strawberry puree edible films (Peretto *et al*., 2014). Carvacrol improved water barrier of bench-cast edible films from apple (Du *et al*., 2008) and tomato purees, but the same behaviour was not observed in its continuous-cast counterparts, probably because of the increased carvacrol evaporation resulting from higher drying temperatures.

4.4.2. Oxygen barrier

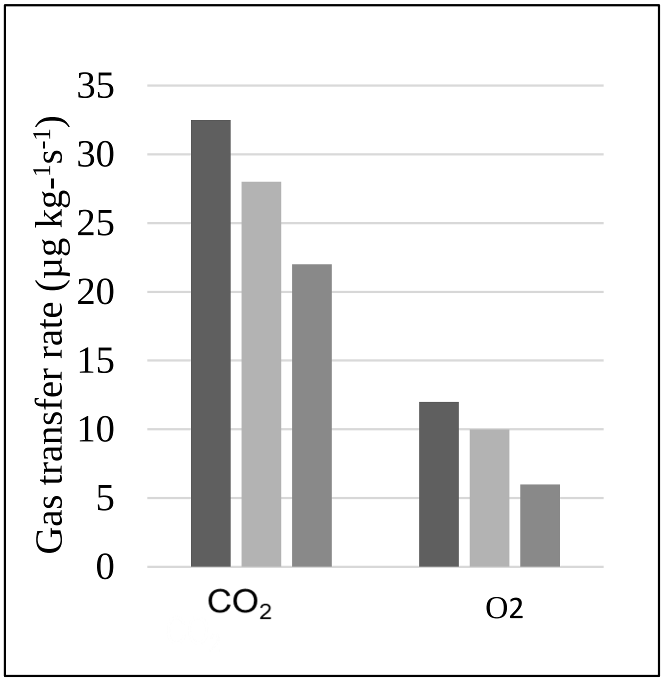
It is highly desirable that food exposure to oxygen is limited since it can lead to oxidation as well as changes in sensory qualities like odour, color, flavor, texture and nutritional losses (Sothornvit and Pitak 2007).Since hydrocolloids are mostly polar in nature, the resulting films are expected to be good barriers to non-polar gasses, including oxygen (Wang *et al*., 2011). The oxygen permeability values of edible films based on fruits and vegetables are higher than that of synthetic polymer films ,thus , extending stability of foods highly susceptible to oxidation (McHugh *et al*., 1996), and also retarding respiration rates of fruits and vegetables (McHugh and Senesi 2000).

Table 7: Oxygen permeability of films

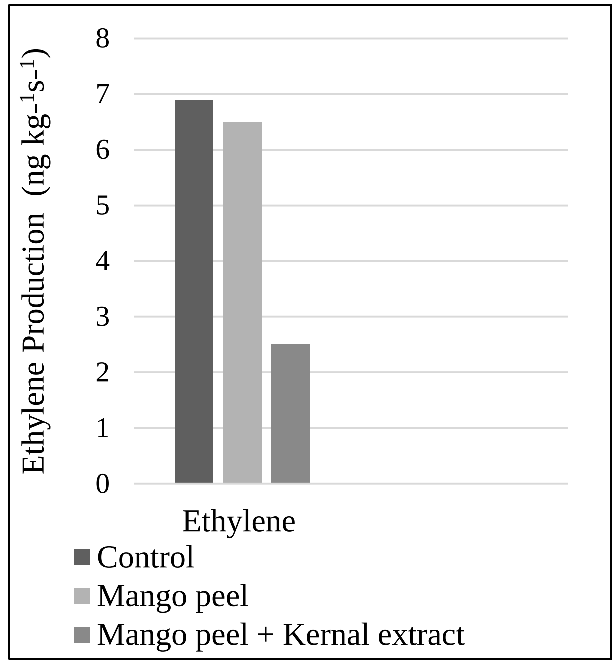
Film	**Binding agent**	**Oxygen permeability (O_2P) (cm ^{3} µm/ m^2/d/kPa)**	**References**
Papaya	Starch, Gelatin	7.50 - 8.20	Tulamandi *et al*., 2016
Carrot	Corn starch, CMC, Gelatin	11.70 - 12.50	Wang *et al*., 2011
Banana	Pectin	22.50 - 41.00	Sothornvit and Pitak, 2007
Apple	LMP	63.00 - 83.60	Du *et al*., 2008
Low density polyethylene(LDPE)		1870.00	MHugh *et al*., 1996
High density polyethylene(HDPE)		427.00	MHugh *et al*., 1996

4.4.3. Co_2 Barrier

Peaches coated with mango seed kernel extract resulted reduction in both gas transfer rate of gases like Co2 and O2. It also reduced the ethylene production, there by delayed ripening (Torres-León *et al*., 2018).



3(a)



3(b)

Figure 3: (a) Gas transfer rate and (b) Ethylene production of peach coated with mango coatings

4.5 Antioxidant properties

Fruits and vegetables are reported as the most important natural source of antioxidants. They are rich in phytochemical compounds such as vitamins and secondary metabolites such as phenolic compounds, sterols, carotenoids, saponins, and glucosinolates, which are known as free radical scavengers. Incorporating properly processed fruits and vegetables into the polymer matrix offers the advantage of synergism, which enhances the antioxidant capacity of particular components. Studies have shown probable synergistic effect between phenolic compounds and carotenoids.

Indian gooseberry puree (IGP) incorporated methyl cellulose (MC) film with Indian gooseberry extract (IGE) extended shelf life of roasted cashew nuts (RCN) by 90 days, due to the antioxidants like gallic acid, catechol, phloroglucinol, pyrogallol and vitamin C. The phenolic content and antioxidant activity increased with increase in the concentration of Indian gooseberry extract (Suppakul *et al*., 2016).

Table 8: Antioxidant activity of IGE - free / IGE- incorporated IGP - MC films

Concentration of IGE (%w/w)	Total phenolic content (mg GA / L)	Antioxidant activities	
		DPPH scavenging (%)	FRAP (TE µm / ml)
0	29.74 ± 0.29[a]	56.43 ± 3.51[a]	73.05 ± 1.03[a]
0.25	30.14 ± 0.18[ab]	63.92 ± 2.92[b]	86.32 ± 2.93[b]
0.50	30.26 ± 0.08[b]	72.61 ± 1.41[c]	107.78 ± 0.73[c]
0.75	30.37 ± 0.06[b]	76.34 ± 2.59[cd]	121.28 ± 1.13[d]
1.00	30.46 ± 0.19[b]	82.92 ± 1.30[d]	128.62 ± 3.38[e]

4.6 Antimicrobial properties

Edible films based on fruits and vegetables can act as carriers of active compounds, including antimicrobials, which may either be immobilized into the film matrix and play their role upon contact with food surface or be slowly released into foodstuffs. Comparing the antimicrobial activity of the film forming formulation to that of the dried film is a useful tool for evaluating the effect of the drying procedure on the antimicrobial performance of the resulting material.

Rojas-Gra¨u *et al*. (2007) incorporated apple puree edible films with the same essential oils or with their major antimicrobial compounds, namely, carvacrol, citral, and cinnamaldehyde, respectively. The inhibition zones of *E. coli* O157:H7 created around films incorporated with the antimicrobial compounds were greater than those around films added with the original essential oils. Among all the treatment carvacrol, the active compound of oregano essential oil, have the most pronounced antimicrobial effect.

Otoni *et al*. (2014), incorporated papaya puree films with cinnamaldehyde nano emulsions of different droplet sizes. While all films were able to inhibit *Escherichia coli, Salmonella enterica, Lysteria monocytogenes* and *Staphylococcus aureus*, greater antimicrobial efficiencies were obtained for nano emulsions of smaller droplets, allowing one to boost the antibacterial activity of edible films based on fruits and vegetables containing low preservative contents.

Table 9: Effect of essential oils on antimicrobial activity of apple puree film

Essential oil and oil compounds	**Concentration (%w/w)**	***Escherichia coli***	
		Inhibitory zone (mm^2)	**Inhibitory effect under film**
Control	0.0	0.0	-
Oregano oil	0.1	49.8	+
Carvacrol	**0.1**	**68.4**	**+**
Lemongrass oil	0.5	40.8	+
Citral	0.5	49.8	+
Cinnamon oil	0.5	19.6	+
Cinnamaldehyde	0.5	40.8	+

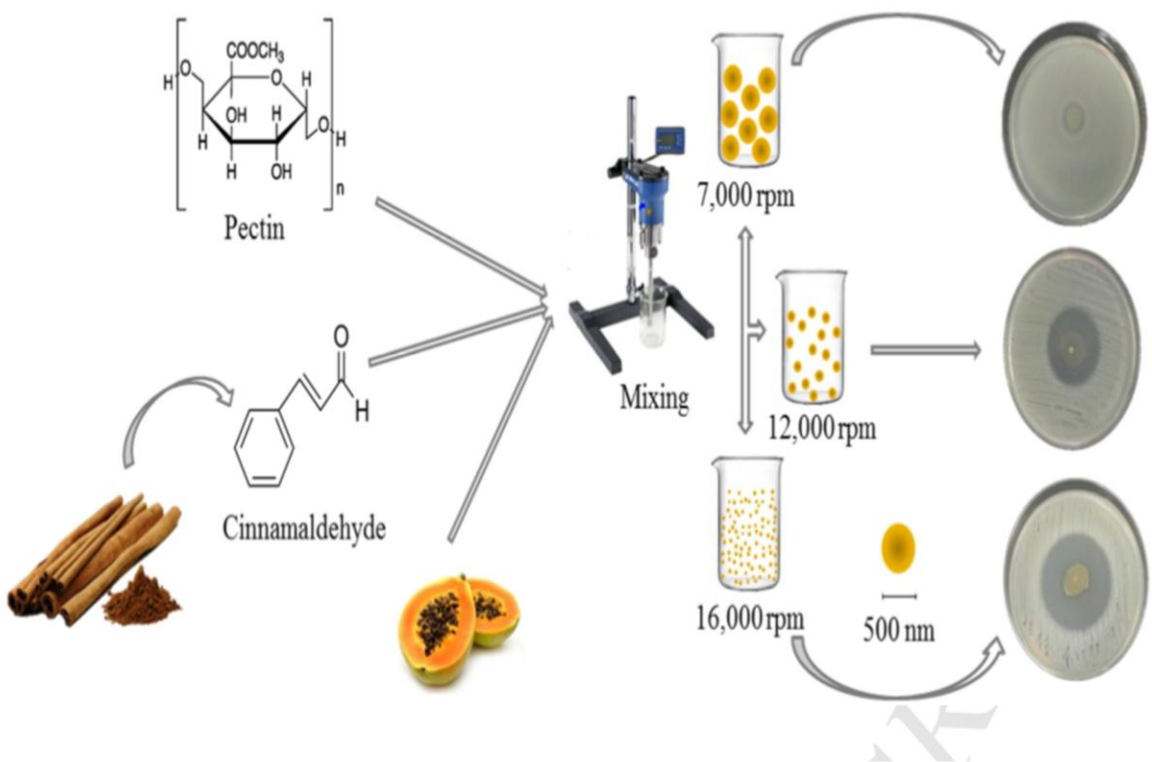
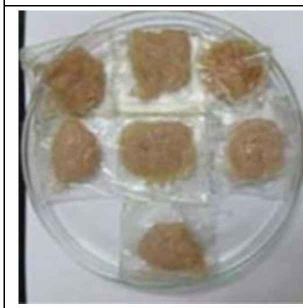


Plate 12: Antibacterial effect of cinnamaldehyde nanoemulsion in papaya film

The shelf life of chicken meat packed in Langra mango peel extract (LMPE) incorporated Poly vinyl alcohol (PVA) film extended to nine days under chilled storage condition. The antioxidants gallic acid, quercetin and antibacterial, mangiferin are responsible for this desirable trait (Kanatt, and Chawla, 2017).

Table 10: Shelf life of chicken meat packed in PVA films with LMPE

Total bacterial count (log cfu/g)	**Storage period (days)**				
	0	**3**	**7**	**10**	**12**
Meat packed in PVA film with out LMPE					
	5.90	6.17	6.26	NA	NA
Meat packed in PVA film with LMPE					
	4.90	4.60	4.45	5.41	5.79

Borah *et al*. (2017) made a biopolymer film by incorporating clove essential oil (1.5%) in to potato peel and sweet lime pomace (PP-SLP) film. Then these films were used for wrapping of bread and stored for five days and found that the films of potato peel and sweet lime pomace with essential oil shows the reduction in their surface microbial count, even less than that of a polyethylene wrapped bread.

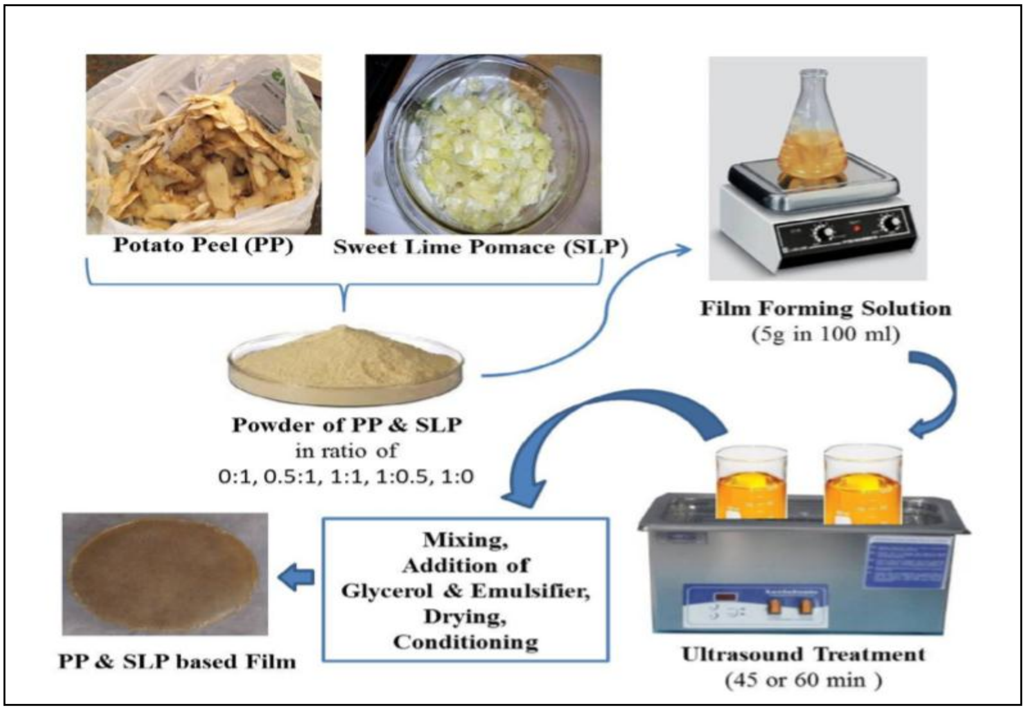


Plate 13: Procedure for preparation of potato peel sweet lime pomace film

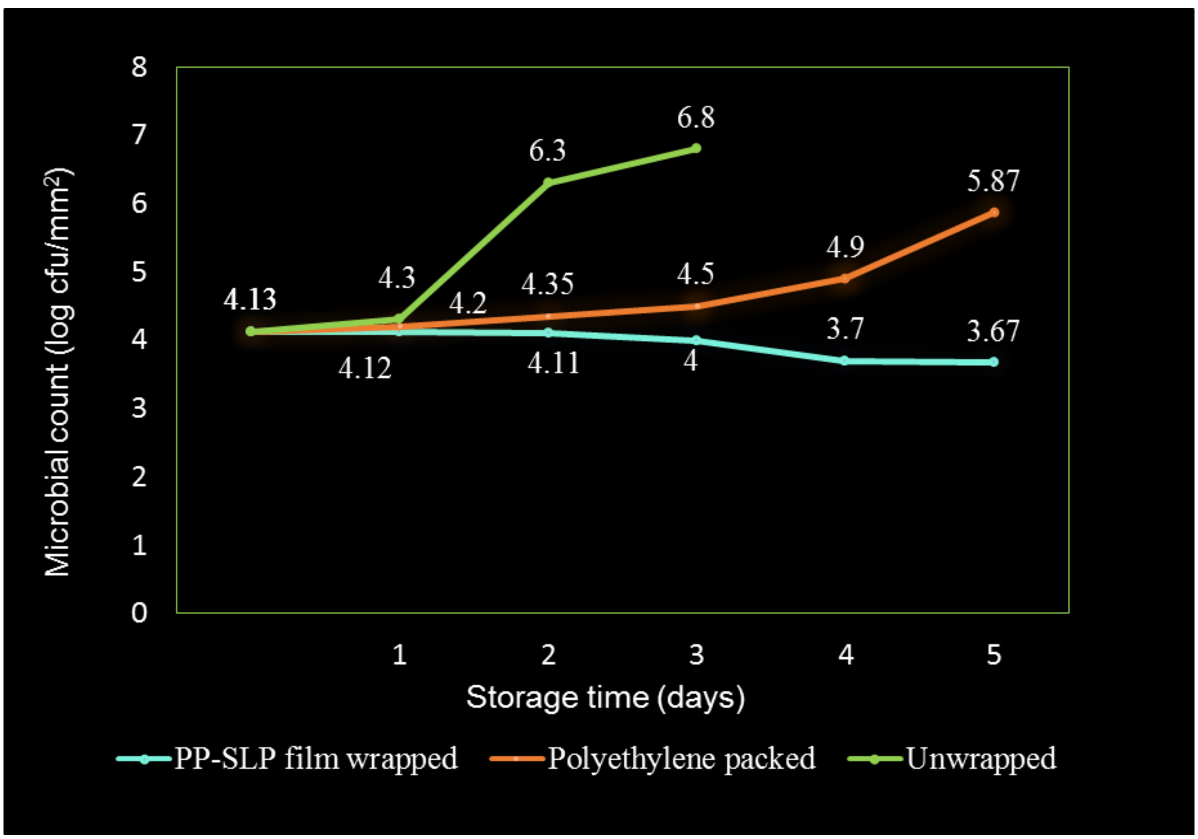


Figure 4: Effect of potato peel - sweet lime - clove oil film on bread quality

5. Potential applications

Fruit and vegetable based films can be used as food wraps such as sushi wraps and sandwich wraps. Films having low melting point, can be used as oral disintegrating films, which will melt in mouth. Thermally stable films can be used as oven bags or cooking bags, can tolerate high temperature.

Active packaging is the other field of application, provide extended shelf life due to the presence of active compounds like antimicrobials and antioxidants. Moreover, the fruit and vegetable based films itself can be consumed as snacks called fruit leather.

Plate 14: Sandwich wrap

Plate 15: Sushi wrap

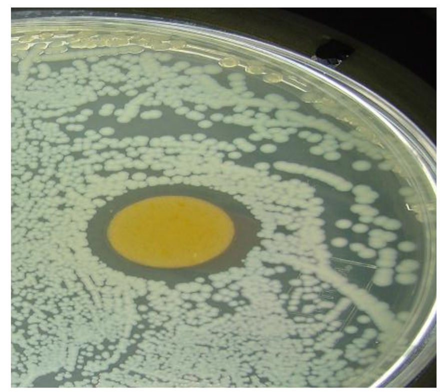


Plate 16: Active packaging

Plate 17: Fruit leather

Plate 18: Cooking bag

Plate 19: Melt in mouth

6. Conclusion

The nutritional and functional properties of naturally occurring compounds in edible films based on fruits and vegetables stand out as unique characteristic distinguishing them from conventional films. In a world increasingly focused on health and environment, applications of edible films on food products are expected to result in reduced food losses.

7. Discussion

1. Is the fruit and vegetable wraps available in India?

Ans: Now, it is not commercially available in our country. But research works are going on fruit and vegetable based films.

2. Can this film tolerate higher temperature?

Ans: Yes, it can tolerate higher temperature, even up to oven temperature.

3. What is the price of the fruit wraps?

The price is about $ 0.8/wrap

4. Do the flavour of the film affect the identity of food packed by it?

Ans: Yes. There are films with or without flavours. So the consumer can decide as per their wish.

5. Are these coatings washed out by water?

Ans: Yes. They are water soluble coating, so it can be washed out before eating.

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9. Abstract

KERALA AGRICULTURAL UNIVERSITY

COLLEGE OF HORTICULTURE, VELLANIKKARA

Department of Post Harvest Technology

PHT: 591 Master's Seminar

Student	: Harya Krishna V.	Venue : Seminar Hall
Admission no.	: 2018-12-016	Date : 28-11-2019
Major Advisor	: Meagle Joseph P.	Time : 10:45 am

'Eat your food with wrappers'

Abstract

Food wastage is reported to be approximately 1.3 billion tonnes per year globally, in which fruits and vegetables contribute to 50 per cent loss (FAOUN, 2015). Food processing sector plays a key role in reducing the loss, but according to MoFPI (2018), about 15 per cent fruit and vegetable wastes are generated by this sector. Moreover, plastic packaging material of processed food products are becoming great threat to environment. One of the best solutions for these problems is developing edible food packaging materials such as films and coatings from the surplus fruits, vegetables and residues of processing industries, which are green alternatives for a sustainable life on earth.

Fruit and vegetable residues, pomaces, extracts, juices and purees along with suitable binding agent and plasticizer, have matrix forming properties to produce edible packaging material with good physical and mechanical properties. The edible films based on fruit and vegetable are alternative means of nutrient intake, including pigments and polyphenols with antioxidant capacity.

Edible films are good oxygen barriers, extending stability of foods that are highly susceptible to oxidation (McHugh *et al*., 1996) and retarding respiration rates of fresh fruits and vegetables (McHugh and Senesi, 2000). The nanocomposite formulations incorporated to the film improved water vapour permeability (WVP) and mechanical properties. Chitosan nanoparticles reduced the WVP of guava puree films from 2.09 to 1.58 g mm/m^2/h/KPa (Lorevice *et al*., 2012) and from 3.03 to 1.90 g mm/m^2/h/KPa in banana puree films (Martelli *et al*., 2013). The use of

amaranth starch nanocrystals as reinforcement in amaranth protein film improved its tensile strength (Condes *et al*., 2018).

Fruit and vegetable based films improve the shelf life of food products. The shelf life of roasted cashew nuts were extended to 90 days when coated with composite film of Indian gooseberry extract (Suppakul *et al*., 2016). Antimicrobials incorporated fruit and vegetable films protect food from microbial spoilage. Clove oil incorporated potato peel - sweet lime pomace based film wrapped bread resulted in reduction of surface microbial count (Borah *et al*., 2017).

The nutritional and functional properties of naturally occurring compounds in edible films based on fruits and vegetables distinguish them from other conventional films. In a world increasingly focused on health and environment, applications of edible films on food products are expected to result in reduced food losses.

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